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SATURN S-II QUALITY ASSURANCE TECHNIQUES

CRITICAL PROCESS CONTROL

Volume VII - Metallic Materials

30 October 1970

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TECHNICAL REPORT INDEX/ABSTRACT

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ABSTRACT

THIS VOLUME IS SUBMITTED TO NASA AS PART OF THE EFFORT BY NORTH AMERICAN ROCKWELL'S SPACE DIVISION TO DOCUMENT SPECIAL SKILLS DEVELOPED DURING THE SATURN S-II PROGRAM. THIS EFFORT PROVIDES DOCUMENTS WHICH WILL ENABLE QUALIFIED PERSONNEL UNFAMILIAR WITH THE PROGRAM TO CARRY OUT EFFICIENT OPERATIONS IN FUTURE S-II PRODUCTION.

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Space Division
North American Rockwell

FOREWORD

This volume is submitted to the National Aeronautics and Space Administration as part of the effort by North American Rockwell Corporation's Space Division to document special skills developed during the Saturn S-II Program. This effort, performed under Contract NAS7-200, provides documents which will enable qualified personnel unfamiliar with the program to carry out efficient operations in future S-II production.

This is Volume VII of S-II Critical Process Control, which emphasizes the Quality Engineering Aspects of critical process control including selected inspection techniques. The complete set includes:

S-II Critical Process Control (SD 70-557)

- Vol. I - Adhesive Bonding
- Vol. II - Foam Insulation
- Vol. III - Primers and Coatings
- Vol. IV - Foil Seals and Potting
- Vol. V - Contamination
- Vol. VI - Chemical Processing
- Vol. VII - Metallic Materials
- Vol. VIII - Raw Material Control

S-II Nondestructive Processes (SD 70-556)

- Vol. I - Requirements and Procedures N72-15471
- Vol. II - Radiographic References ATS# 13728

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INTRODUCTION

The intent of this volume is to describe the major verification techniques employed by Quality Assurance in concert with the production welding of components for the Saturn S-II stage. This will enable qualified personnel unfamiliar with the program to carry out efficient operations in future S-II activities.

The S-II stage, the second stage booster for the Saturn V launch vehicle, is a cylindrical structure measuring 81.5 feet in length and 33 feet in diameter. The airframe consists of both pressurized and unpressurized sections. The pressurized sections form the LO_2 and LH_2 propellant tanks and are fabricated from the 2014-T6 aluminum alloy utilizing the DC GTA (gas tungsten arc) welding process exclusively.

The cylindrical section of the LH_2 tank is comprised of six individual cylinder elements, each made up of four quarter panels. The quarter panels are formed to the required configuration and joined by vertical splice welds to produce a cylinder section. The cylinder sections are then stacked and joined with circumferential welds.

The forward LH_2 bulkhead for the LH_2 tank is comprised of 12 gore segments. Each gore segment is rough-machined from plate stock, formed, and Chem-milled to finished dimensions, and joined by machine fusion welding to other gore segments to form the bulkhead assembly. At the apex of the bulkhead, a ring of circular plate stock is welded to the gore sections forming a tie-in point for the invididual gores. The forward LH_2 bulkhead is then joined to the uppermost or No. 6 LH_2 cylinder section of the stage by a circumferential weld.

The integral vehicle structure separating the LO_2 tank from the LH_2 tank is called the common bulkhead. The common bulkhead assembly forms the barrier between dissimilar liquid propellents and consists of a forward facing sheet and an aft facing sheet joined by adhesive bonding. Honeycomb core is sandwiched between the facing sheets and serves as the structural core member and insulator between the two propellent tanks. The face sheet assemblies are fabricated in a manner similar to the forward LH_2 bulkhead. The common bulkhead assembly is fusion-welded to the bottom of the No. 1 cylinder portion of the LH_2 tank by a circumferential weld.

The LO_2 tank consists of two bulkhead assemblies that are welded together. The aft LO_2 bulkhead assembly is similar in construction to the forward LH_2 bulkhead but contains a heavier section at the apex of the structure designated as the dollar section. This is the member to which the LO_2 sump is attached. The aft LO_2 bulkhead assembly is welded to the common bulkhead assembly by a circumferential or girth weld to form the LO_2 tank.

Each Saturn S-II stage contains 25,118 inches of weld per stage and, therefore, the welding techniques utilized on the stage are designated as a "Critical Process."

This document pertaining to Quality Assurance control of weld processes is divided into seven sections as follows:

1. Acceptance Testing of Fusion-Welding Equipment
2. Weld Operator and Inspector Certification Requirements
3. Machine Certification - Equipment
4. Preweld Operations
5. In-Process and Post-Weld Operations
6. Repair Weld Certifications
7. Weld Quality Data Book

1.0 ACCEPTANCE TESTING OF FUSION WELDING EQUIPMENT

Technical acceptance testing of fusion welding equipment is conducted by Quality Assurance (QA) as specified in North American Rockwell Corporation, Space Division Policy F-425, dated 10 December 1962. Quality Assurance is responsible for the acceptable performance of the equipment before its release to Manufacturing for product use in accordance with engineering requirements defined in the applicable specifications governing fusion welding on the Saturn S-II Program. Such documents generally consist of a procurement specification and an acceptance test specification. This section describes the detailed methods employed by Quality Assurance for verifying compliance with the criteria established in these specifications.

1.1 GENERAL REQUIREMENTS

North American Rockwell's Space Division (NR SD) submits an equipment procurement specification and an acceptance test specification to manufacturers and/or suppliers of fusion welding equipment when bid requests are submitted for the purchase of a new fusion welding equipment system.

The equipment procurement specification, initiated through the NR SD Tooling Department, defines the required parameters to which the equipment must conform. The specification is reviewed by Quality Assurance, Engineering, and Manufacturing to assure that the primary weld equipment package and all known functional accessory items required in the basic system are included.

The responsible Quality Assurance technical group receives a copy of the completed procurement specification and prepares an acceptance test specification for the specific equipment system. This specification is structured to assure that the equipment purchased conforms to the end-item requirements established in the equipment procurement specification. The acceptance test specification stipulates that a complete or partial acceptance test must be performed using the equipment at the supplier's facility. This is to prevent the receipt of equipment at NR SD that will require major modifications by the supplier. The acceptance test specification is used as a guide for the partial acceptance test conducted at the supplier facility.

The acceptance test specification is normally divided into primary groups for subsystem operation capability. A primary group is defined as any subsystem function having a significant effect on the performance and reliability of the overall fusion welding equipment system being procured. The following primary groupings are considered typical for Saturn S-II machine welding equipment system functions:

1. Power supply
2. Skate system (automatic welding head)
3. Weld torch
4. Filler wire feed system
5. Weld carriage and weld head travel drive motor systems
6. Electronic and mechanical control systems
7. Accessory welding cables, hoses, wiring
8. Equipment carriage

An example of a typical fusion welding acceptance test specification, machine-type GTA (gas tungsten arc), is shown in Section 1.2. This document contains the primary component groups and the detail requirements listed under each group heading. It is applicable for most types of semi-automatic GTA machine fusion welding equipment used at NR SD on the Saturn S-II Program. However, engineering requirements for specific machine types may require the addition or deletion of certain accessory items to the basic welding equipment. The requirements described in the fusion welding acceptance test specification are presented with a typical cover sheet and memorandum to the Purchasing Department defining Quality Assurance criteria for the procurement package.

After Quality Assurance approval of the partial acceptance test is attained at the supplier's facility and receipt of the equipment at NR SD, the final acceptance test is initiated and directed by Quality Assurance personnel in accordance with acceptance test specification requirements. Where contractual requirements necessitate the calibration of critical measuring devices such as meters and dial controls, this is accomplished during the final series of acceptance tests at NR SD facilities. The objective is a total systems calibration of the integrated instrument package associated with individual weld equipment units.

All instruments used for measuring and controlling in-process machine variables during the acceptance tests are precalibrated to a known standard by Quality Assurance personnel associated with the NR SD Metrology Laboratory. The in-process test results are continually evaluated during the conduct of the test program and, upon completion, all pertinent data are correlated to the applicable requirements. When discrepancies are found, the equipment supplier is notified and the defective component repaired or replaced as required to assure compliance with the equipment acceptance test requirements. The supplier normally provides an experienced weld engineer familiar with the process and the equipment to aid in completing the acceptance test.

If the machine/equipment system does not operate satisfactorily or the acceptance test results are unacceptable, the item is rejected. The Quality Assurance representative issues a letter defining the areas of nonconformance and requests that specific corrective action be initiated. Upon completion of equipment system repair/replacement, the acceptance demonstration test is repeated.

After the successful completion of the acceptance test, Quality Assurance issues a letter to the Purchasing Department stating that the equipment conforms to the requirements of the acceptance test specification and is acceptable for unrestricted use in the manufacturing work area on deliverable flight hardware.

1.2 ACCEPTANCE TEST SPECIFICATION (TYPICAL EXAMPLE)

A typical example of a welding acceptance test specification is presented in Appendix A.

2.0 WELD OPERATOR AND INSPECTOR CERTIFICATION REQUIREMENTS

The manual and machine fusion-welding processes (and the inspection of welds) are classified as critical skills at the Space Division. Quality Assurance and their designated representatives assure that only qualified and certified manual and machine welding operators and inspectors are utilized during the manufacture and inspection of Saturn S-II weldments. This section describes the detailed methods employed by the Quality Assurance organization for verifying compliance with the criteria established and referenced in this manual.

2.1 GENERAL REQUIREMENTS (OPERATORS/INSPECTORS)

Certification of welding operators and inspectors is used as a method of assuring that only personnel who are properly trained and qualified in Space Division welding requirements and techniques will be utilized on Saturn S-II production parts. Both machine welding and manual welding techniques are included in the critical process category and all welders and inspectors are required to complete specified hours of specialized training and testing instruction before they are allowed to perform welding or inspection operations on production assemblies.

Quality Assurance provides the technical support to the weld training department (Manpower Development) by establishing such documents and procedures as quality control specifications, weld test specimen configurations, and new welding process development methods. In addition, the Quality Assurance organization provides specimen preparation and testing facilities.

Saturn S-II weld process specifications (References 2-1 and 2-2) require weld operators to be certified in accordance with applicable Quality Control specifications (References 2-3 and 2-4). Recertification also must be accomplished as stated in references 2-3 and 2-4.

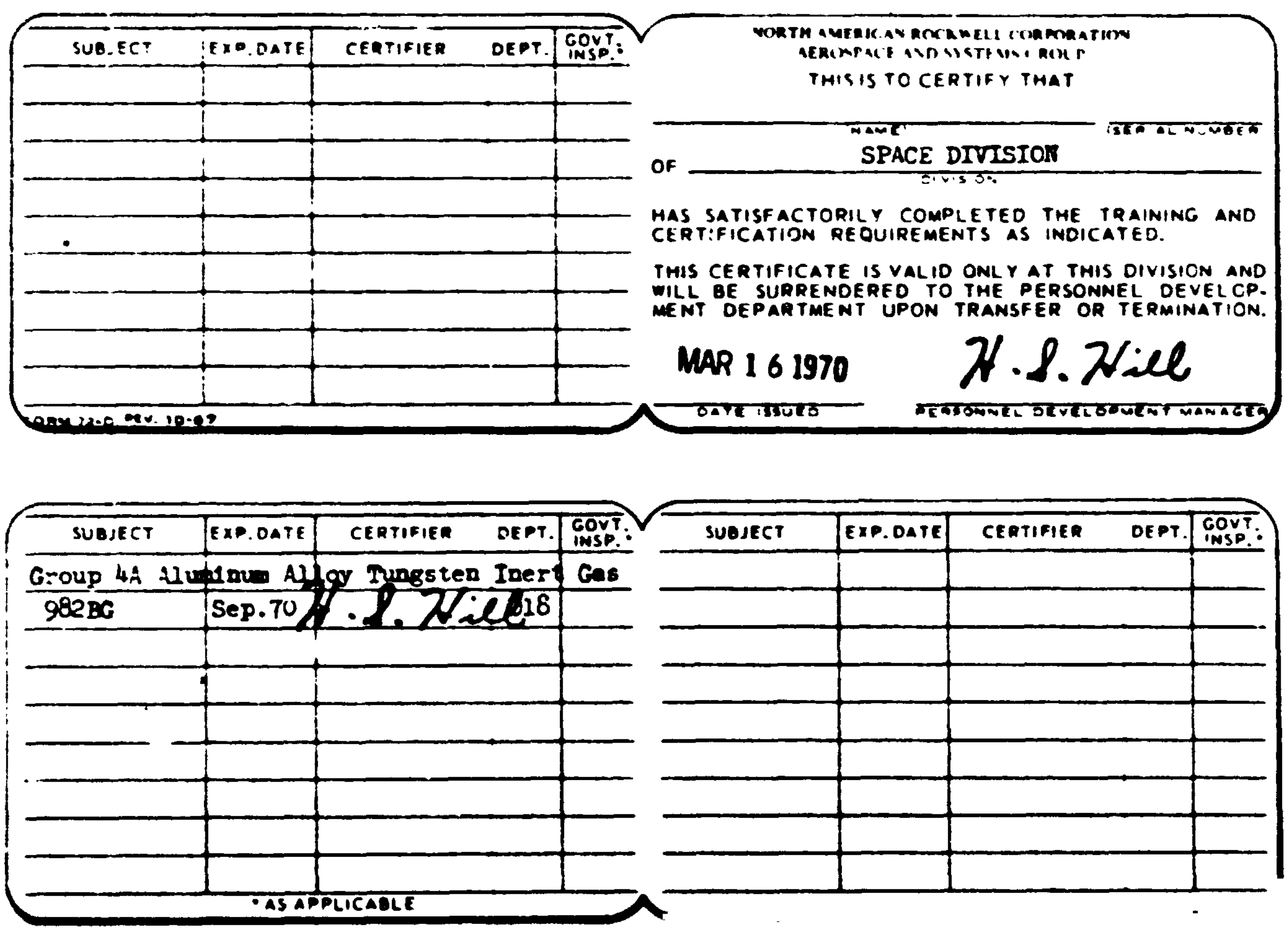
The inspection of fusion welds, a critical skill, requires Quality Assurance certification of the representative performing the weld process that he inspects. To become certified, the quality representative must satisfactorily complete a formal training course related to weld processing and presented by the training department (Manpower Development). The certification course for fusion weld inspectors requires a minimum of

21 hours of instruction, which covers (1) interpretation of weld symbols, (2) preweld inspection for cleanliness and weld fit-up sequences, (3) types of material, and (4) post-weld visual inspection methods.

2.2 MANUAL WELD CERTIFICATIONS - OPERATORS

Original Certification

Prior to performing production welding sequences, each welding operator is required to have a valid certification in accordance with the applicable process specification requirements associated with each combination of metals, welding position, and welding processes he is required to use. In addition, all manual welders are required to pass an NR standard vision test every 12 months. Glasses or other vision corrective aids, if used to pass certification tests, must be used during production welding. The welder's Certification Card (Figure 2-1) is annotated to show that corrective aids were used during certification or recertification tests.



SUBJECT	EXP. DATE	CERTIFIER	DEPT.	GOVT. INSP.*

FORM 72-D REV. 10-67

NORTH AMERICAN ROCKWELL CORPORATION
AEROSPACE AND SYSTEMS GROUP
THIS IS TO CERTIFY THAT

NAME — SERIAL NUMBER

OF SPACE DIVISION
DIVISION

HAS SATISFACTORILY COMPLETED THE TRAINING AND CERTIFICATION REQUIREMENTS AS INDICATED.

THIS CERTIFICATE IS VALID ONLY AT THIS DIVISION AND WILL BE SURRENDERED TO THE PERSONNEL DEVELOPMENT DEPARTMENT UPON TRANSFER OR TERMINATION.

MAR 16 1970 — H. S. Hill
DATE ISSUED — PERSONNEL DEVELOPMENT MANAGER

SUBJECT	EXP. DATE	CERTIFIER	DEPT.	GOVT. INSP.*
Group 4A Aluminum Alloy Tungsten Inert Gas				
982BG	Sep. 70	H. S. Hill	18	

*AS APPLICABLE

SUBJECT	EXP. DATE	CERTIFIER	DEPT.	GOVT. INSP.*

Figure 2-1. Weld Operator Certification Form Card (Form 72-D)

Manual fusion welders are required to take an original certification test at the following times:

1. When first hired or when rehired

2. When the welder can requalify for certification after his previous certification had been revoked

3. When applying for certification in a new metals group, position, or process

4. When a welder has not performed production welding for 90 days or more.

The welder applicant must demonstrate his ability in welding to the satisfaction of Manpower Development before starting his original certification test. The demonstration will correspond to the fusion welding process, material, and position to be used by the welder on S-II production work.

The certification material used for each metal alloy group is listed in Table 2-1. The required weld tests for an original certification in the flat position and for tube welds are listed in Tables 2-2 and 2-3. They are comprised of butt welds (Figure 2-2); fillet welds (Figure 2-3); corner welds (Figure 2-4); flange welds (Figure 2-5); butt welds - tubing (Figure 2-6); flange welds - tubing (Figure 2-7); box welds (Figure 2-8); and lap-fillet welds - tubing (Figure 2-9). An original certification for welds in other positions is comprised of (1) a butt-weld joining two pieces of material, each 0.250 inch thick (Figure 2-2), (2) a fillet-weld joining two pieces of 0.250 inch thick material (Figure 2-3), and (3) a fillet-weld joining two pieces of 0.500 inch thick material.

The preparation of materials and equipment for welding tests is considered part of the demonstration of the welder's abilities. Each welder being tested must follow this preparation sequence: cleaning of material, selection of the electrode holder or torch, electrode type or tip configuration, filler material, weld setup and backup gas typical of the production application, and the adjustment of machine controls. For purposes of these tests, a single process is used throughout the welding of the specimens used in the certification procedure.

The following basic operational welding positions require separate certifications - flat, vertical, horizontal, and overhead - except that a welder holding valid certifications for welding in the vertical, horizontal, and overhead positions does not need a separate certification for welding in the flat position.

After completion of the original certification test, Manpower Development sends the welded test specimens and a completed Request for Certification Training Form No. 907-M-15 (Figure 2-10) to Quality Assurance for testing and

Table 2-1. Material Groups for Manual Weld Certification

Group	Material	Cert. Test Material
I:		
Alloy steel	4130, 4140, 4340, 8630, 8640, 4135, 4335, H-11	4130
Carbon steel	1010, 1015, 1020, 1025	
II - Corrosive and heat-resistant alloys		
Hardenable	AM-350, AM-355, PH15-7Mo, 17-4Ph, 17-7Ph, A-286	AM-350
Nonhardenable	Type 321, Type 347, 19-9 DX, 19-9 DL, 304L	304L
III:		
Nickel-base alloys	Monel, Inconel, Inconel X, Rene 41, Inconel 713C, Inconel 718, Hastelloy B, C, W, X, Nionel, Numetal	Inconel
Copper-base alloys	Amcoloy 97, Class RCU	
IV:		
Alluminum alloys	1100, 3003, 5052, 6061, Tens 50, 356, 2014, 2219	6061
V:		
Magnesium alloys	AZ31B, QQ-M-44, Cond. A	As required by Quality Assurance
VI:		
Reactive and other material not listed in other groups	Titanium, Zirconium, Molybdenum, Beryllium, Tantalum, Columbium, Zircoloy, Tungsten	See Note 1

NOTE:

1. Welder's certification valid only on the material or similar alloy of that material in which the certification was made, in all materials of Group VI.
2. Certification for materials other than listed will be conducted under the direction of Quality Assurance or their representative.

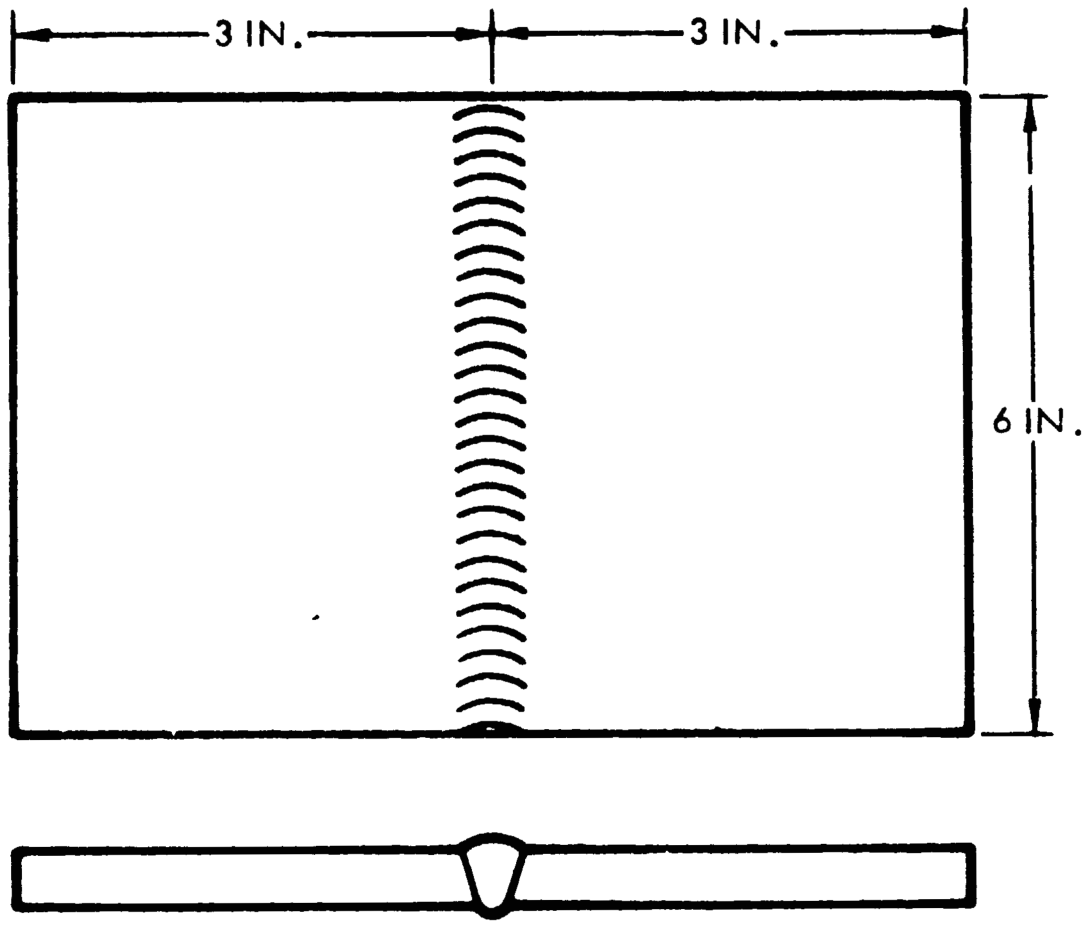
Table 2-2. Joint Types and Material Thicknesses for Flat Position Manual Weld Certification

Welding Process	Material Group	Material Thickness (in.)	Joint Type	Specimen Configuration
Gas	Group IV	0.040 0.060 0.040 0.040 0.060	Butt Butt Flange Corner Corner	Figure 2-2 Figure 2-2 Figure 2-5 Figure 2-4 Figure 2-4
Shielded Metal Arc	All groups	0.125 0.250 0.125 0.125 0.250	Butt Butt Fillet Corner Box	Figure 2-2 Figure 2-2 Figure 2-3 Figure 2-4 Figure 2-8
Gas Tungsten Arc	All groups	0.040 0.125 0.125 0.125 0.250	Butt Butt Fillet Corner Box	Figure 2-2 Figure 2-2 Figure 2-3 Figure 2-4 Figure 2-8
Gas Metal Arc	Group I Group I Group IV	0.125 0.500 0.125 0.250 0.250	Butt Butt Fillet Corner Box	Figure 2-2 Figure 2-2 Figure 2-3 Figure 2-4 Figure 2-8

Table 2-3. GTA Manual Welding Certification for Tubing

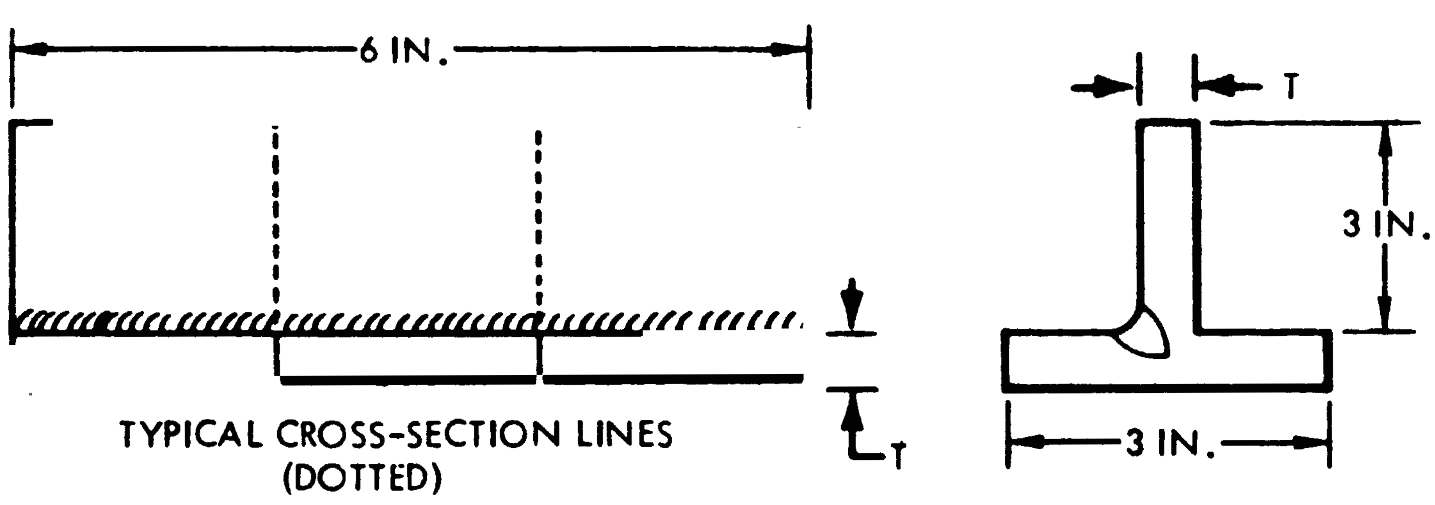
Material Alloy	Tube Diameter (in.)*	Tube Wall Thickness (in.)	Joint Type	Stationary Position	Stationary Configuration
6061	0.250	0.030 ± 0.005	Lap	Horizontal	Figure 2-9
6061	1.000	0.060 ± 0.005	Lap	Vertical	Figure 2-9
304L	0.250	0.030 ± 0.005	Butt	Horizontal	Figure 2-6
304L	0.250	0.030 ± 0.005	Flange	Horizontal	Figure 2-7
304L	3.000	0.030 ± 0.005	Butt	Vertical	Figure 2-6
304L	1.000	0.060 ± 0.005	Flange	Vertical	Figure 2-7

*Tube length will be a minimum of 3 inches



NOTE: WELD IN THE DOWN-HAND POSITION. A SINGLE WELD PASS IS REQUIRED ON 0.040-INCH THICK MATERIAL. MULTIPLE WELD PASSES MAY BE EMPLOYED ON THICKNESSES 0.125-INCH THICK AND GREATER.

Figure 2-2. Butt-Weld Joint Specimens (Manual)



NOTE: SINGLE WELD PASS ONLY FOR 0.040-INCH MATERIAL THICKNESSES; 0.125- , 0.250- , AND 0.500-INCH MATERIAL MAY REQUIRE MULTIPLE PASSES

Figure 2-3. Fillet-Weld Joint Specimen (Manual)

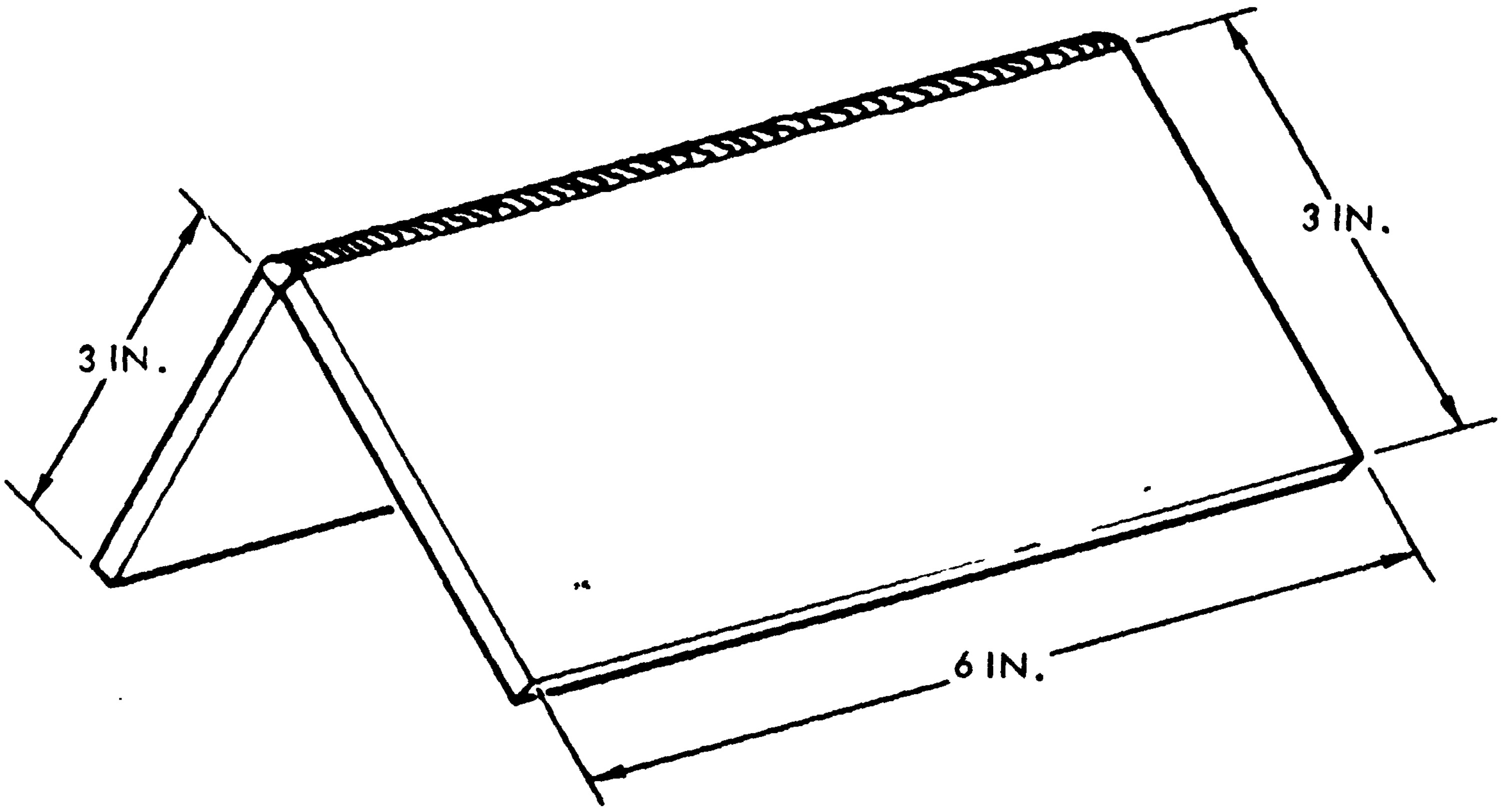


Figure 2-4. Corner Weld Joint Specimen (Manual)

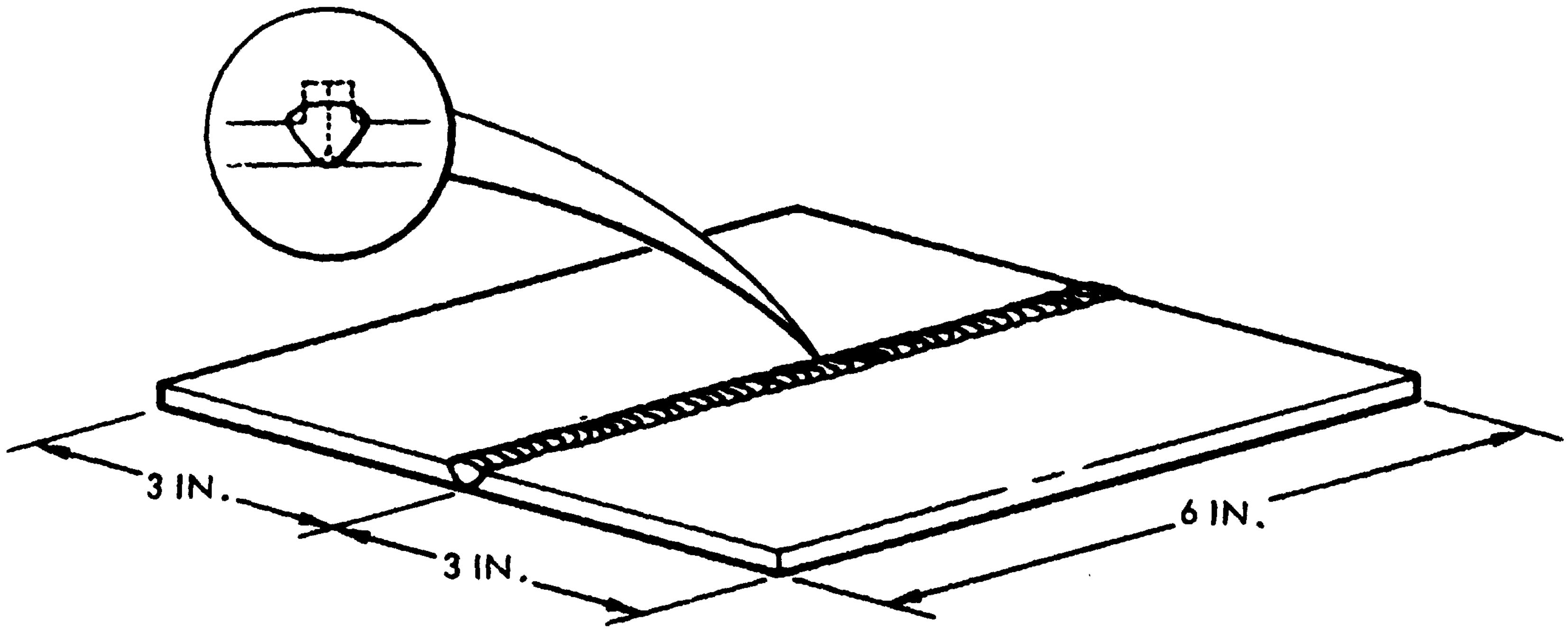


Figure 2-5. Flange Weld Joint Specimen (Manual)

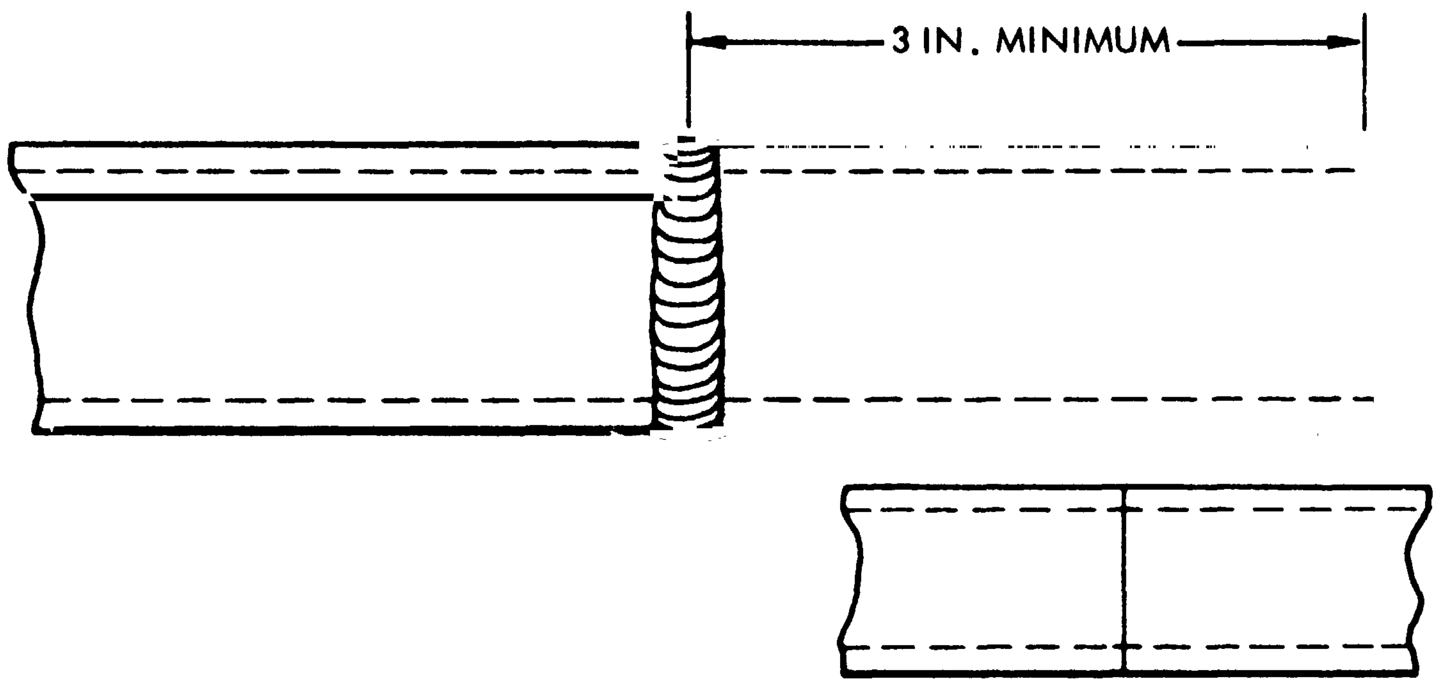


Figure 2-6. Butt-Weld Joint Specimen - Tubing (Manual and Machine)

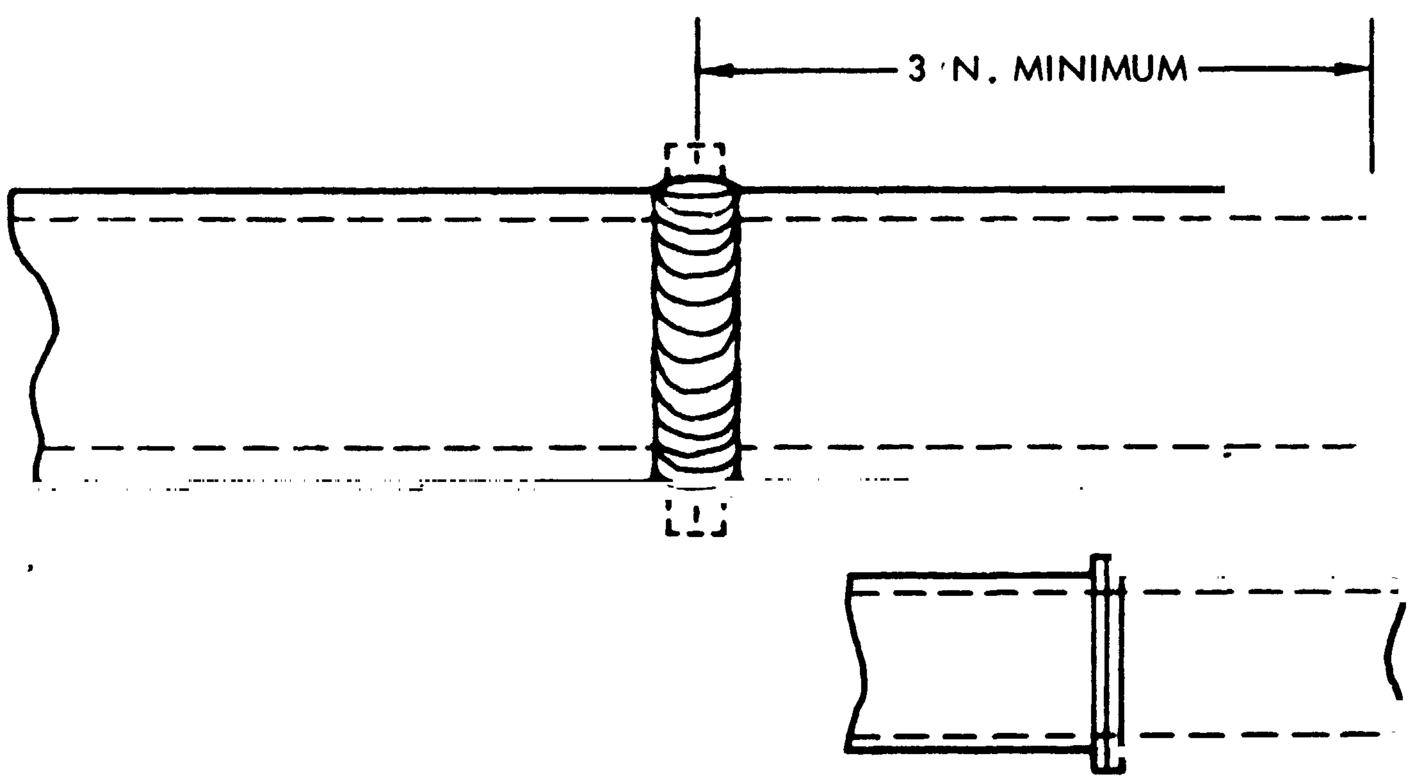


Figure 2-7. Flange Weld Joint Specimen - Tubing (Manual and Machine)

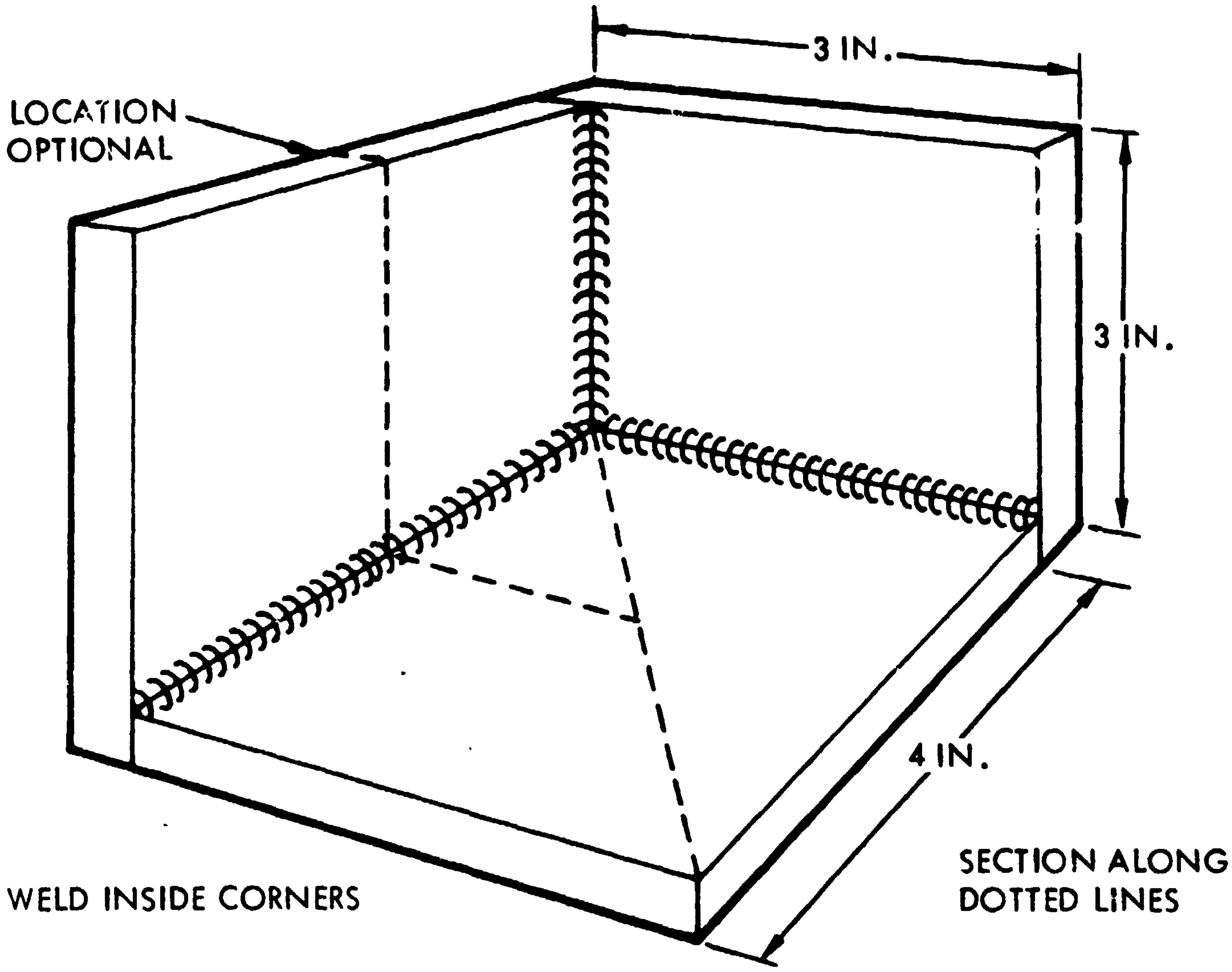


Figure 2-8. Box-Weld Joint Specimen (Manual)

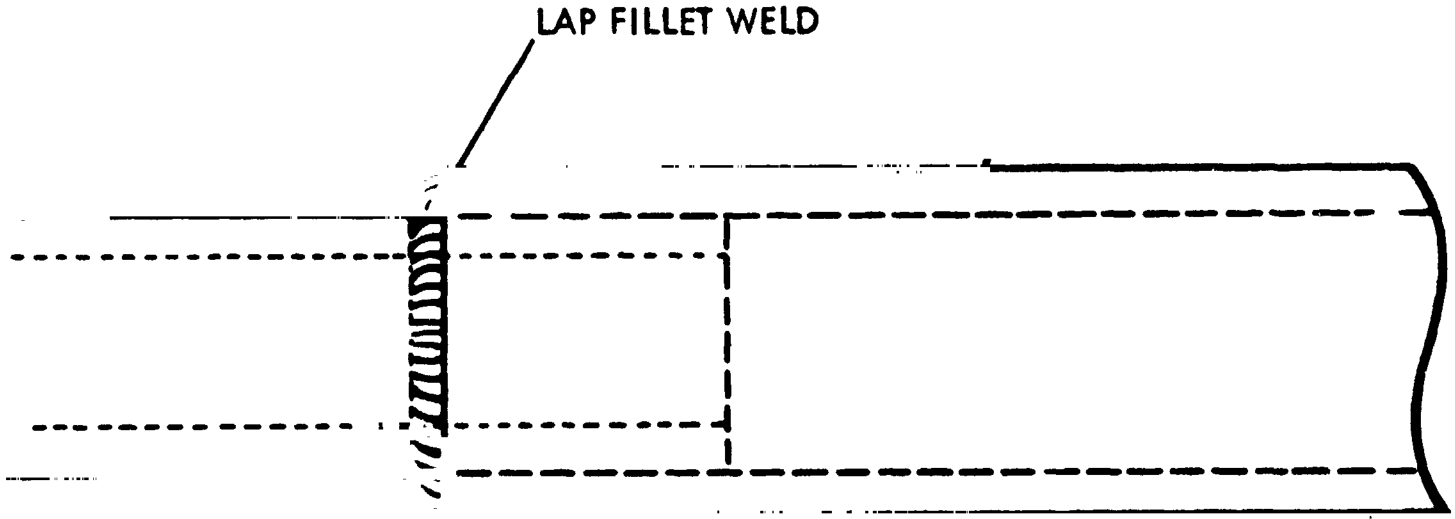


Figure 2-9. Lap-Fillet Weld Tube Specimen (Manual and Machine)

Space Division
North American Rockwell

SPACE DIVISION
NORTH AMERICAN ROCKWELL CORPORATION

REQUEST FOR CERTIFICATION TRAINING

(Please type or print in ink)

Last Name | First | Initial

Department | Group | Serial # | Shift | Grid Location

Job Title

Organization Name | Address

Name of Course

General Supervisor | Mail Code | Phone Ext.

This Section to be Filled out by Manpower Development

Based on Training Records the Employee is:

Ineligible for Certification	Certification Category
Original Certification	Course Code
Recertification	Certification Void After this Date:

EMPLOYEE'S CERT. CARD (FORM 72-D) WAS UPDATED ☐ TYPE NEW CARD ☐

Other Instructions or Remarks:

Instructor/Certifier | Lab Representative | Supervisor Manpower Development

FORM 907-M-15 REV 4-68

Figure 2-10. Request for Certification Training Form evaluation. When one joint from a weld specimen set (five specimens per set) is rejected and there is no evidence of poor workmanship, the welder is allowed to submit one additional test specimen of the same type of weld joint. If this specimen is rejected because of poor workmanship, or two or more weld specimens are rejected, the welder is required to submit another complete set of original certification test specimens after additional training. If all test weld joints are judged satisfactory, the Request for Certification Training form is countersigned by the designated Quality Assurance technical representative and forwarded to Manpower Development. Manpower Development then issues a new certification card or adds the new certification to the welder's existing card.

Specifically, the Quality Assurance technical representative examines and evaluates each weld test specimen. Test methods and the quality requirements for each type of weld joint are listed in Table 2-4. If the test results are acceptable, the signature of the Quality Assurance representative is entered on Form 907-M-15. Copies of the completed form are placed in the welder's permanent file and maintained by Quality Assurance. The original copy is forwarded to and retained by Manpower Development.

Upon receipt of Form 907-M-15, Manpower Development issues or updates the welder's certification card. In the event of a test rejection, the reason for the rejection is noted in the remarks column of Form 907-M-15. Manpower Development is then notified of the rejection by their receipt of Form 907-M-15. The rejected test specimens also are returned to Manpower Development.

Each welder's file consists of a copy of Form 907-M-15 for each of his original certification and recertification tests. Notifications of test failure and disqualification also are maintained in this file, as well as any other applicable documents (such as medical data related to eye examinations).

Recertification

A manual welder can maintain his certified status by demonstrating satisfactory workmanship in accordance with the requirements of Quality Control Specification MQ0701-001 (Reference 2-5) or by the successful completion of a periodic recertification weld test. The continuous certification procedure was not used on the Saturn S-II Program but it is described later in this section for use if needed to control similar weld operations in the future. The periodic recertification weld test procedure was used on the Saturn S-II Program to recertify manual fusion weld operators.

The recertification requirements for manual welding in the flat position requires preparation of a fillet-weld box joint using 0.250-inch thick material (Figure 2-8), except for Group IV (oxygen-hydrogen), in which a 0.060-inch thick butt joint is used. The periodic recertification weld tests for all other manual welding positions (except for tube welds and Group VI alloys) involves the preparation and welding of a fillet-weld joint using 0.250-inch thick material. For Group VI alloys, a fillet joint using 0.250- or 0.125-inch

Table 2-4. Testing Methods and Quality Requirements for Manual Weld Operator Certification

Joint	Test Method	Quality Requirements
Butt	Visual	Weld surfaces will be examined for workmanship and conformance to requirements of applicable NR process specifications
	X ray	Internal weld structure will meet quality requirements of applicable NR process specifications
	Penetrant	Weld surfaces will be examined and meet quality requirements of applicable NR process specifications
Fillet	Visual	Weld surfaces will be examined for workmanship and conformance to requirements of applicable NR process specifications
	Macro-section	Weld geometry will conform to requirements of applicable NR process specification (minimum of two samples)
Flange	Visual	Weld surfaces will be examined for workmanship and conformance to requirements of applicable NR process specifications
	Macro-section	Weld geometry will conform to requirements of applicable NR process specifications (minimum of two samples)
Tube	Visual	Weld surfaces will be examined for workmanship and conformance to requirements of applicable NR process specifications
	Macro-section	Weld geometry will conform to requirements of applicable NR process specifications (minimum of two samples)
	X ray	Internal weld structure will meet quality requirements of applicable NR process specifications
Corner	Visual	Weld surfaces will be examined for workmanship and conformance to requirements of applicable NR process specifications
	Macro-section	Weld geometry will conform to requirements of applicable NR process specifications (minimum of two samples)
	X ray	Internal weld structure will meet quality requirements of applicable NR process specifications
Box	Visual	Weld surfaces will be examined for workmanship and conformance to requirements of applicable NR process specifications
	Macro-section	Weld geometry will conform to requirements of applicable NR process specifications (minimum of two samples)

thick material can be used. For tube welds, one 3-inch diameter, Type 304L corrosion-resistant steel (CRES) tube with a wall thickness of 0.030 ± 0.005 inches will be butt-welded, and one 1-inch diameter, 6061 aluminum alloy tube with a wall thickness of 0.030 ± 0.005 inches will be welded using a lap-fillet joint (Figure 2-9). All tubes will be maintained in a horizontal position during the recertification welding operation.

The manual weld recertification test is accomplished using the same weld process utilized for the original certification. Recertification test specimens and the completed Form 907-M-15 are submitted to Quality Assurance for processing, testing, and evaluation. When test results are determined to be acceptable, Quality Assurance approves the recertification specimens by countersigning the Form 907-M-15 and forwarding it to Manpower Development. When a recertification test specimen is judged to be unacceptable, the welder is allowed to submit one additional test specimen. If the second specimen is also unacceptable, the welder must satisfactorily complete a full certification test after additional weld training.

After receiving the approved Form 907-M-15, Manpower Development signs the certification card and inserts the new certification expiration date on the card.

A certified welder transferring to the Space Division from other divisions must pass a recertification test in the process, position, or material in which he carries a currently valid certification. If he does not have a valid certification in the process, position, or materials group in which he will be welding, he must satisfactorily complete an original certification test before he welds production parts.

2.3 MACHINE WELD CERTIFICATIONS - OPERATORS

Original Certification

This section applies to all welders operating semiautomatic fusion welding machines at the Space Division on the Saturn S-II Program. Semiautomatic welding machines have the fusion welding torch as a component of a mechanical carrier. Preset machine variables (electronic controls) may be adjusted or interrupted by the operator at any time during the welding sequence.

The requirements for operator vision tests and conditions in which original machine welding certifications are required, are the same as those described for manual welding.

The following machine welding processes are covered in this section:

1. Submerged arc (sub-arc)

2. Inert gas shielded tunsten arc (GTA)

3. Inert gas shielded arc with consumable electrode (GMA)

4. Electron beam (EB)

All machine welders and applicants are required to weld their original certification test specimens in the training department or its designated welding location. Each certification test specimen is welded in the same position as that required for production welding. The material alloy used in the weld tests must be that specified for each material group (Table 2-5). The material alloy and thickness dimensions specified for each metals group are listed in Table 2-6. The type of weld filler-wire alloy used in each metal group must conform to the applicable production weld process specification.

The test plates used for machine-weld certification are flat sheets or plates measuring 4 inches wide and 24 inches long. The two test plates are then joined by welding to produce each weld test specimen. Two weld test specimens are required for each original weld certification; one specimen must be welded for each of the thicknesses indicated in Table 2-6.

Welding of the certification test specimens is limited to a single process and the same method as that required for production service. The test plates must each contain a minimum of 20 inches of continuous acceptable weld. A single weld pass is required on test materials less than 0.130 inch thick and two weld passes may be used on materials whose thickness is greater than 0.130 inch when limited by welding machine capability. Welding is not permitted on the root side of any weld test specimen.

Part of the test requires the welder to prepare the test specimens, select the proper accessory equipment and materials, and determine optimum machine settings.

Specific training courses are employed to instruct each welder applicant in fusion welding familiarization and machine welding techniques. The training includes descriptions of fusion welding processes, weld design symbols, functions of process specifications, filler metal identification methods, and preheat and postheat treatment of welds. Vocational training in actual machine welding includes weld joint preparation, weld setup, equipment adjustments, and control functions.

After completing the training course, the welder applicant is required to take a written test. Each applicant must pass this examination before

Table 2-5. Material Groups for Machine-Weld Certification

Group	Material	Cert. Test Material
I - Carbon and alloy steels		
Class IA - alloy steel	4130, 4140, 4340, 8630, 8640, 4135, 4335, H-11	4130
Class IB - carbon steel	1010, 1015, 1020, 1025	1015
II - Corrosion and heat resistant steels		
Class IIA - hardenable	AM-350, AM-355, PH-15-7 Mo, 17-4PH, 17-7PH, A-286	17-7PH
Class IIB - nonhardenable	Type 321, Type 347, 19-9DX, 19-9DL	18-8
III - Nickel and copper alloys		
Class IIIA - nickel base	Monel, Inconel, Inconel X, Rene 41, Inconel 7130, Inconel 718, Hastelloy B, C, X, Y, Nionel, Mu Metal	Inconel
Class IIIB - copper base	Amcoloy 97, Class RCV	Amcoloy 97
IV - Aluminum alloys	1100, 3003, 2014, 2024, 5052, 5456, 6061, Tens. 50, 356, 2219	6061
V - Magnesium alloys	AZ31B, QQ-M-44, Cond. A	AZ31B
VI - Reactive and refractory Alloys	Titanium, Zirconium, Molybdenum, Beryllium, Tantalum, Columbium, Zircoloy, Tungsten	Note 1

NOTE:
1. Materials for certification in Group VI will be for specific application.
2. Certification in Group I, Class IA, qualifies for welding IA and IB materials.
3. Certification in Group II, Class IIA, qualifies for welding IIA and IIB materials.
4. Certification for materials not listed will be determined by the Quality Engineering Laboratory.
5. Certification in Group VI will be valid only on the specific material certified in test.

Table 2-6. Material Thickness for Machine-Weld Certification

Range*	Group IA	Group IB	Group IIA	Group IIB	Group IIIA
Low	0.030	0.030	0.020	0.020	0.200
High	0.250	0.120	0.125	0.125	0.125
Range*	Group IIIB	Group IV	Group V	Group VI	
Low	0.020	0.125	0.020	0.020	
High	0.125	0.500	0.125	0.125	

Material of 0.062-inch thickness may be substituted for 0.020 where condition of welding fixture cannot provide uniform joint alignment and chilling.

additional training in machine welding techniques. The written test will consist of no fewer than 35 questions jointly agreed upon by the Training Department and the designated Quality Assurance group. The written test is subject to the approval of the Quality Assurance group.

Applicants who pass the written test are then instructed in actual machine fusion welding practice. Each applicant must then demonstrate to the satisfaction of the welding instructor his ability to produce a good machine fusion weld. Welders and applicants who have passed the written examination and demonstrated satisfactory welding ability will be permitted to weld test plates for the original machine weld certification test.

Machine-welded certification test specimens and required forms are submitted to Quality Assurance for testing and evaluation.

The certification weld test specimens are subjected to visual, radiographic, and fluorescent penetrant examination; weld irregularities must not exceed the maximum allowables listed in the applicable process specifications.

A fusion weld certification test report (Form 907-M-15) is prepared by the training representative for each machine weld test specimen submitted for certification approval. The form contains the welder's name, department, clock number, and all other pertinent data relating to the certification and process.

After completion of the original certification test weld specimens, the training department sends them and a completed Request for Certification Training form (907-M-15) to Quality Assurance for testing and evaluation. If the machine weld test specimen is unacceptable, Quality Assurance notifies the training department of the test discrepancy. As long as there is no evidence of poor workmanship, the welder is allowed to prepare and weld one additional weld test specimen of the same configuration and material. Failure of the retest specimen disqualifies the applicant. The welder is required to receive additional training before machine welding another complete original certification test.

The Quality Assurance technical representative examines and evaluates each weld specimen for internal and surface discontinuities. When any suspect area is encountered, it is evaluated in accordance with the requirements listed in the applicable process specification. If the test specimens are accepted, the Quality Assurance representative signs the Form 907-M-15. In the event of a test rejection, the reason for the rejection is noted in the remarks column of Form 907-M-15. Manpower Development is then notified of the rejection by their receipt of Form 907-M-15. The rejected test specimens are returned to Manpower Development. A copy of the completed Form 907-M-15 is then placed in the welder's permanent file maintained by

Quality Assurance. The original copy of the Form 907-M-15 is retained by Manpower Development. Upon receipt of an accepted form, Manpower Development issues or updates the welder's certification card.

Quality Assurance maintains a file on each welder. The file contains a copy of all 907-M-15 forms, notifications of test failures or disqualifications, and any other pertinent documents (such as medical data related to eye examinations).

A certified machine welder transferring to the Space Division from other NR facilities is required to pass a recertification test in the process, position, or material in which he carries a current certification to become eligible to weld Saturn S-II parts and assemblies. If the welder does not hold a current certification in the process, position, or materials group in which he will be welding, he is required to pass a complete original certification prior to machine welding S-II production parts.

Recertification

The certified status of a machine welder is maintained by continuing to demonstrate satisfactory workmanship in accordance with the requirements of Quality Control Specification MQ0701-001 or by the successful completion of a periodic recertification weld test. As noted previously, the continuous certification procedure was not used on the Saturn S-II Program. The periodic verification weld test used at NR/SD to recertify machine fusion weld operators consists of one set of test plates of a thickness selected by Manpower Development from Table 2-6.

Welding procedures, inspection methods, and acceptance procedures are identical to those previously outlined for the original machine weld certification process.

2.4 CONTINUOUS CERTIFICATION PROCEDURE

Although the continuous certification procedure was not used on the Saturn S-II Program, it is described here for possible future use.

NR's Continuous Evaluation Recertification Technique (NACERT) continuously evaluates certified production fusion welders for workmanship quality and applies to both the manual and machine welding processes. The welder's performance records are compiled and computed on a monthly basis during each regular six-month certification period. Recertification is based on this continuous monthly record for workmanship quality as compared to NACERT standards. The NACERT program functions on inputs of production welding data accumulated on Form 918-T, Production Welding Record for NACERT (Figure 2-11). Quality Assurance evaluates each report of defective welding to determine the cause, thus assuring that the welder is charged only with welding defects attributed to his own workmanship. When a defect is caused by something other than welder's error, corrective action

NACERT CHART POSTING GUIDE

LINE	MATERIAL GROUP	PROCESS	COLORCODE	
1	IA&B	MA	————————	BLACK
2	IA&B	TIG	— — — — — —	BLACK
3	IA&B	MIG	— - — - — -	BLACK
4	IIA	TIG	— — — — — —	RED
5	IIB	TIG	— —B— — -	RED
6	IIA	MIG	— - — - — -	RED
7	IIB	MIB	— -B- — -	RED
8	IIIA	MA	————————	GREEN
9	IIIA	TIG	— — — — — —	GREEN
10	IIIA	MIG	— - — - — -	GREEN
11	IIIB	MA	———B———	GREEN
12	IIIB	TIG	— —B— — -	GREEN
13	IIIB	MIG	— - B - — -	GREEN
14	IV	TIG	— — — — — —	BLUE
15	IV	MIG	— - — - — -	BLUE
16	V	TIG	— — — — — —	BROWN
17*	VI	TIG	— —Ti— — -	PURPLE
18	SPECIAL CERTIFICATION			

*GROUP VI, USE SOLID LINE WITH CHEMICAL SYMBOL

Figure 2-11. Production Welding Record (NACERT) Form

is initiated by Quality Assurance. The NACERT program is intended to provide continuing improvement in welding operator proficiency and weld product quality.

Procedure

The Production Welding Record (NACERT) Form 918-T serves as the data link between the various production welding operations and Quality Assurance. Form 918-T is prepared by the production welding operator who perform the welding task. Form 918-T is then submitted to the inspector who checks the weld. The Inspector makes a brief written disposition on the form and submits it to the Quality Assurance technical representative. The entries by both welder and inspector must be accurate and uniform. To assure proper preparation of Form 918-T, a procedural guide is provided in the following paragraphs. The entries to be made by the welding operator are as follows:

1. Date - date the welding operation was performed (start and stop)
2. Time - time the welding operation was performed (start and stop)
3. Welder Stamp - identification stamp of the operator performing the welding task
4. Department No. - Number of department responsible for performing the weld
5. Welding Specification - identification number of the applicable general process specification used for welding
6. Part No. - affected part number
7. Release No. - release portion of the work charge number
8. Welding - applicable welding method; manual or machine
9. Welding Process - applicable abbreviation for the welding process employed (GTA, GMA, etc.)
10. Materials Group No. - group number of like metals being joined; specific alloys are identified when joining dissimilar metals
11. Welding Position - position of the weld deposit (flat, horizontal, vertical, or overhead)
12. Joint Type - identification of the weld joint configuration

13. Welding Backing - type of backup tooling employed (if any)

14. Inches Welded - inches of weld deposited

15. Remarks - additional information that may assist in the evaluation of welding performance.

Entries made by the welding inspector are as follows:

1. Inspection Date - date of the inspection

2. Inspector Stamp - identification stamp of the responsible weld inspector

3. Inspection Method - inspection technique (e.g., visual, X-ray)

4. Inches Inspected - length of the weld in inches

5. Inches Acceptable - inches welded minus inches defective

6. Inches Defective - inches of defective weld detected

7. Type of Defect - description of the defect

8. Disposition - part disposition - squawk number, material review number, etc.

9. Remarks - any additional information needed

When more than one inspection technique is used on a weld joint, an additional Form 918-T must be prepared to include the disposition for each inspection. A separate Form 918-T also is prepared for multipass welds when an inspection is performed after each weld pass.

Defects should be described on the Form 918-T by denoting the types and the dimensions. For NACERT calculations, defect areas which consist of less than one linear inch are considered as one inch.

Upon receipt of a Form 918-T which reports a defect, Quality Assurance investigates the cause. The welding operator is charged only with defects attributed to his workmanship. Quality Assurance takes action to correct any conditions in which weld quality problems are not the result of welder workmanship. Forms reporting defects which are welder's error are marked in red in the right-hand margin.

NACERT Accounting Procedure

The data contained in the 918-T forms are accounted for on a monthly basis (the NACERT month ends on the 15th). The accumulated 918-T forms are sorted separately for each welding operator. In addition, each welding operator's 918-T forms are separated into certification classes (welding process and materials group). The number of inches welded and the number of defective inches of weldment checked in red will be totaled. The percentage of defective weldment is computed as follows:

$$100 \times \frac{\text{Total Inches Defective*}}{\text{Total Inches Welded}} = \text{Rejection Rate Percent}$$

The accumulated data are posted on the individual welder's NACERT chart (using graph paper similar to Keuffel & Esser Graph 359T-11). A NACERT chart sample (Figure 2-12) and the NACERT chart posting guide (Table 2-7) are included to aid in proper posting of NACERT data.

Table 2-7. NACERT Chart Posting Guide

Line	Material Group	Process	Colorcode	
1	IA&B	MA	———	Black
2	IA&B	GTA	– – –	Black
3	IA&B	GMA	— — —	Black
4	IIA	GTA	– – –	Red
5	IIB	GTA	– – B – –	Red
6	IIA	GMA	— — — — —	Red
7	IIB	GMA	— B – –	Red
8	IIIA	MA	———	Green
9	IIIA	GTA	– – –	Green
10	IIIA	GMA	— — —	Green
11	IIIB	MA	—B—	Green
12	IIIB	GTA	– – B – –	Green
13	IIIB	GMA	— - B - —	Green
14	IV	GTA	– – – – –	Blue
15	IV	GMA	— - — - —	Blue
16	V	GTA	– – – –	Brown
17*	VI	GTA	– – Ti – –	Purple
18	Special Certification			

*Group VI, use solid line with chemical symbol

*Total defective inches attributed (charged) to welder error

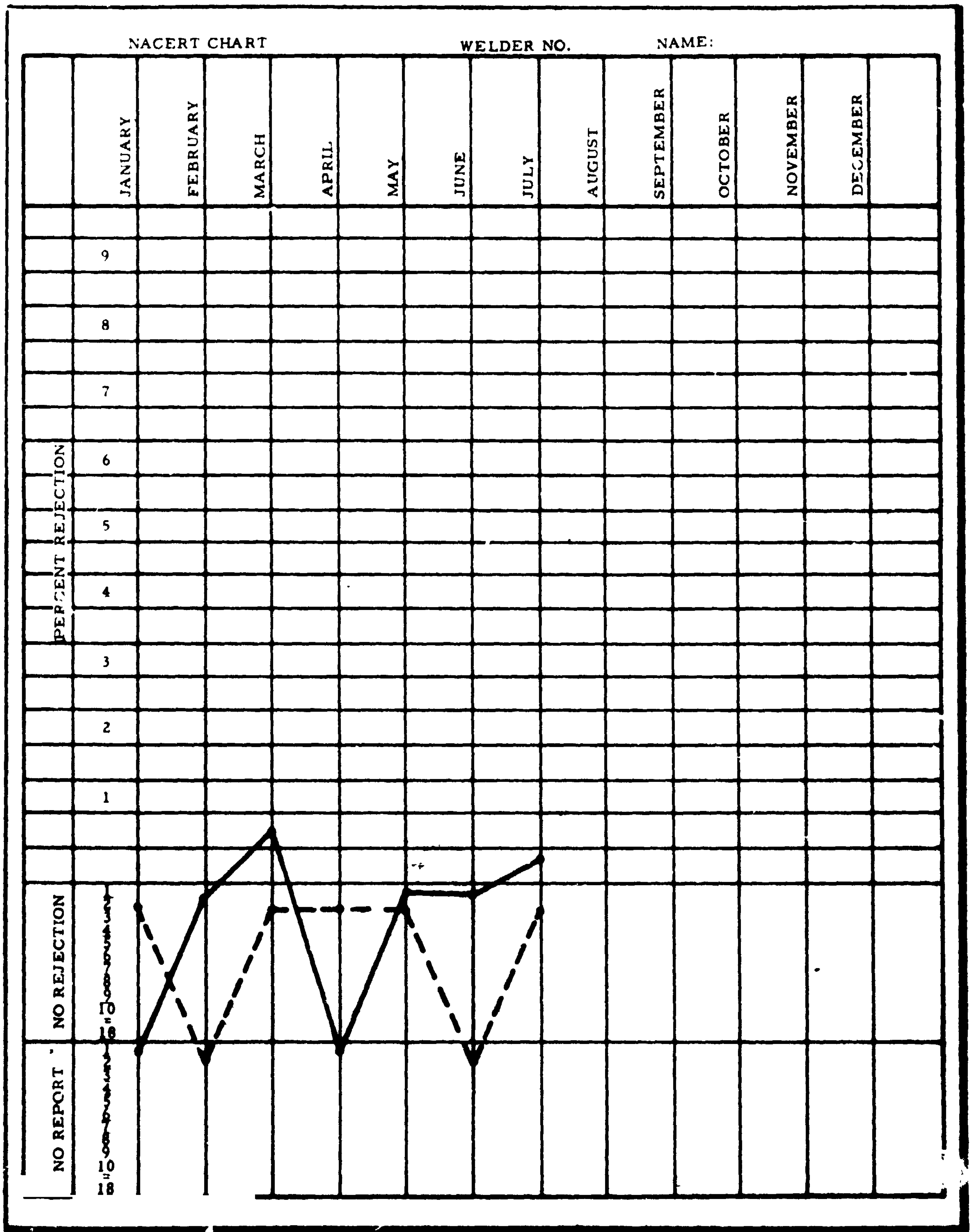


Figure 2-12. NACERT Chart Sample

The NACERT chart is established in three sections: No Report, Number of Rejections, and Percent Rejection. The No Report and Number of Rejections sections are codified into 18 lines each. Each line represents a metals group and welding process.

The NACERT posting guide gives a breakdown of each corresponding line number on the NACERT chart. The posting guide code system is comprised of colors, each representing a metals group and a line code representing a process.

The typical example shown in Figure 2-12 represents a control document for a welding operator who carries two certifications: metal arc (GMA), Group I (low alloy and mild steels), and gas tungsten arc (GTA), Group I (low alloy and mild steels). Figure 2-12 shows that the operator had no report for GMA, Group I, welding in January and sufficient reports in February containing no rejections. Both months are posted on line one in the proper section and connected by a solid black line. Similarly, the operator had a sufficient number of reports for GTA welding with no rejection in January and no reports in February. Both months are posted on Line 2 of the proper section and connected with a broken black line.

The No Report section entries indicate the welder has not performed any welding in the particular metals group and process for more than two consecutive months. The No Rejections section indicates the welder had performed welding operations and that the work was satisfactory. When the welder has reported rejections during the NACERT month the percentages are posted in the Percent Rejection section. In the example, the welder had a rejection rate of 0.8% in March when using the metal arc welding process. This is shown by the solid black line connecting the February No Rejections posting and the March Percent Rejection posting.

Charts are maintained to show the overall production welding performance for each combination of metals group and welding process. The chart data are accounted and posted on the chart in the same manner as for the individual production welder.

Individual welding operator rejection rates which fall below the overall production rejection rate are posted in the No Rejection section.

The performance of each welder due for recertification is checked for evidence of satisfactory work. Welding operator certifications which meet the requirements for recertification under the provisions of NACERT are reported to the Management Development Training Department on or before the first day of each month.

2.5 REFERENCES

2-1. NR SD Process Specification MA0107-016, Revision H; Machine Fusion Welding of Aluminum Alloys for Saturn S-II Vehicle.

2-2. NR SD Process Specification MA0607-017, Revision B; Manual Fusion Welding of Aluminum Alloys for Saturn S-II Vehicle.

2-3. NR SD Quality Control Specification MQ0701-004, Revision C; Certification of Machine Fusion Welders.

2-4. NR SD Quality Control Specification MQ0701-003, Revision D; Certification of Manual Fusion Welders.

2-5. NR SD Quality Control Specification MQ0701-001, Revision A; Recertification of Fusion Welders by Evaluation of Workmanship (NACERT).

3.0 MACHINE CERTIFICATION - EQUIPMENT

Quality Assurance verifies that all Saturn S-II weld schedules produce end-item weldments conforming to the applicable process specifications. A Quality Assurance technical representative surveys all preweld, weld, and postweld, nondestructive and destructive testing operations performed on certification weld panels to verify conformance to data recorded on the welding schedule.

3.1 GENERAL REQUIREMENTS

NR SD Process Specifications MA0107-016 and MA0607-017 require the use of a certified weld schedule (Form No. 971-D) prior to the initiation of any production welding operation. The certification weld schedules are required by Process Specification MA0107-016, Revision H, to consist of a minimum of two sections which define: (1) the basic welding parameters used by Manufacturing for each weld and; (2) supplemental welding parameters (if any) used by Manufacturing after documentation and approval by Quality Assurance.

The Quality Assurance representative verifies that the preproduction test welds made for certification purposes utilize preestablished weld parameters defined in a fusion welding process requirement schedule (Form No. 971-D). The certification test welds must simulate the production parts to be welded with respect to (1) material section thickness, (2) alloy, (3) material heat treat condition, (4) weld joint preparation, (5) maximum allowable gap, (6) general configuration, (7) parts being fabricated in either the actual or simulated production weld fixture, and (8) test welds being processed employ the actual welding equipment that will be used on the production parts or assemblies.

The preproduction certification test welds are subjected to the applicable mechanical or physical properties tests specified herein. Prior to destructive and nondestructive testing, the weld panels are subjected to the same processes which affect mechanical or weld joint strength properties as are production welds, such as (1) chemical etching, (2) weld bead reinforcement removal, (3) mechanical deformation characteristics related to joint mismatch (offset) and/or peaking, and (4) thermal treatments associated with artificial aging, stress relief, or adhesive bonding sequences. Prior to initiating test specimen preparation operations (machining) for mechanical properties testing sequences, acceptance of the welded test plates must be obtained after subjecting the welds to visual, fluorescent penetrant, and radiographic inspection examinations to verify conformance to the requirements of the applicable process specifications. When acceptable welds are verified, test plates are fabricated into the appropriate test specimen configuration and mechanical properties tests are performed.

Subsequent to completion of all welding and testing sequences, the certification weld schedule (Form 971-D) is validated by obtaining approval signatures from designated Quality Assurance, Engineering, and Manufacturing representatives. Quality Assurance assigns identification numbers to each weld schedule, and issues a monthly composite weld schedule report which identifies the primary and repair types of welds for which each procedure is currently certified. Weld schedule certification numbers and their corresponding revision letters must be contained in the monthly report to be used for production welding. Quality Assurance personnel perform surveillance over a particular welding operation to verify that the weld schedule number and revision letter (if applicable) intended for use by Manufacturing is valid for a given production weld.

Prior to starting any certification welding operation, Quality Assurance assures that (1) the welding power supply unit conforms to the requirements of the applicable acceptance test, (2) the weld machine has been calibrated and will remain in calibration throughout the scheduled welding sequence, and (3) the weld operator is currently certified in the process to be employed. Section 3-11 references a typical certification weld schedule for the circumferential (or girth) weld joining the aft LO_2 bulkhead to the common bulkhead for the S-II stage.

3.2 SPECIMEN TESTING PROCEDURES - NONDESTRUCTIVE

Subsequent to completion of the welded test specimens for manufacturing weld machine certification, Quality Assurance personnel complete the following inspection tests of the welded certification test plates or panels.

1. The weld bead and adjacent zones are visually inspected to assure compliance with the applicable process specification for:

    a. Undercut

    b. Suckback

    c. Concavity

    d. Incomplete penetration

    e. Off-center weld nugget

    f. Lack of fusion

g. Offset and peaking

h. Surface-type defects such as cracks, porosity, folds, etc.

2. The mechanical test specimens are then radiographically inspected (X-ray) to the requirements of Quality Assurance Specification MQ0501-007, Inspection, Radiographic, and the results correlated with defect acceptance/rejection criteria defined in the internal quality requirements for weldments listed in the applicable process specification.

3. Fluorescent penetrant inspection is performed to the requirements of Quality Assurance Specification MQ0501-004, Inspection, Penetrant Method, and the results correlated with defect acceptance/rejection criteria defined in the weldment surface quality requirements listed in the applicable process specification.

3.3 PREPARATION OF TENSILE STRENGTH SPECIMENS

Uniaxial tensile strength specimens are cut from the weld test plates, machined to the configuration shown in Figure 3-1, and tested to destruction at ambient temperature using a standard, calibrated tensile testing machine with a loading rate of 0.050 inch per minute of head travel. The percentage of elongation incurred in prescribed evaluation zones and the ultimate tensile load are recorded on the form shown in Figure 3-2. A minimum of five tensile specimens comprise one test set. The tensile specimens are not to be tested until a minimum of 36 hours natural aging has elapsed. The specimens are prepared and tested for each of the following types of welds associated with certification requirements.

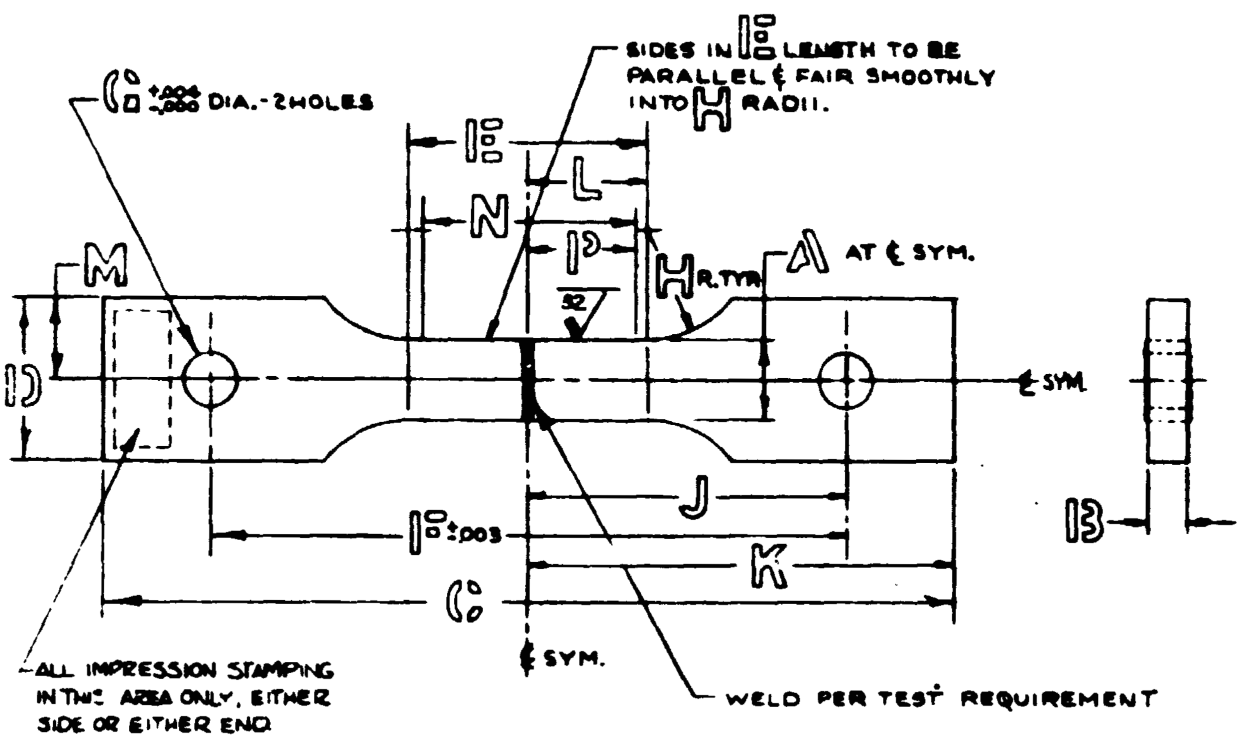
1. A butt weld simulating the as-welded joint. Loading is applied transverse to the weld joint.

2. A butt weld intersected by a subsequent butt (or crossover) weld. The first butt weld in the specimen must be positioned parallel to the applied load. The second weld maintains the maximum preweld gapping specified by the welding schedule.

3. A butt weld in which the welding machine has been stopped and restarted. The restart position must be located in the approximate center of the tensile specimen.

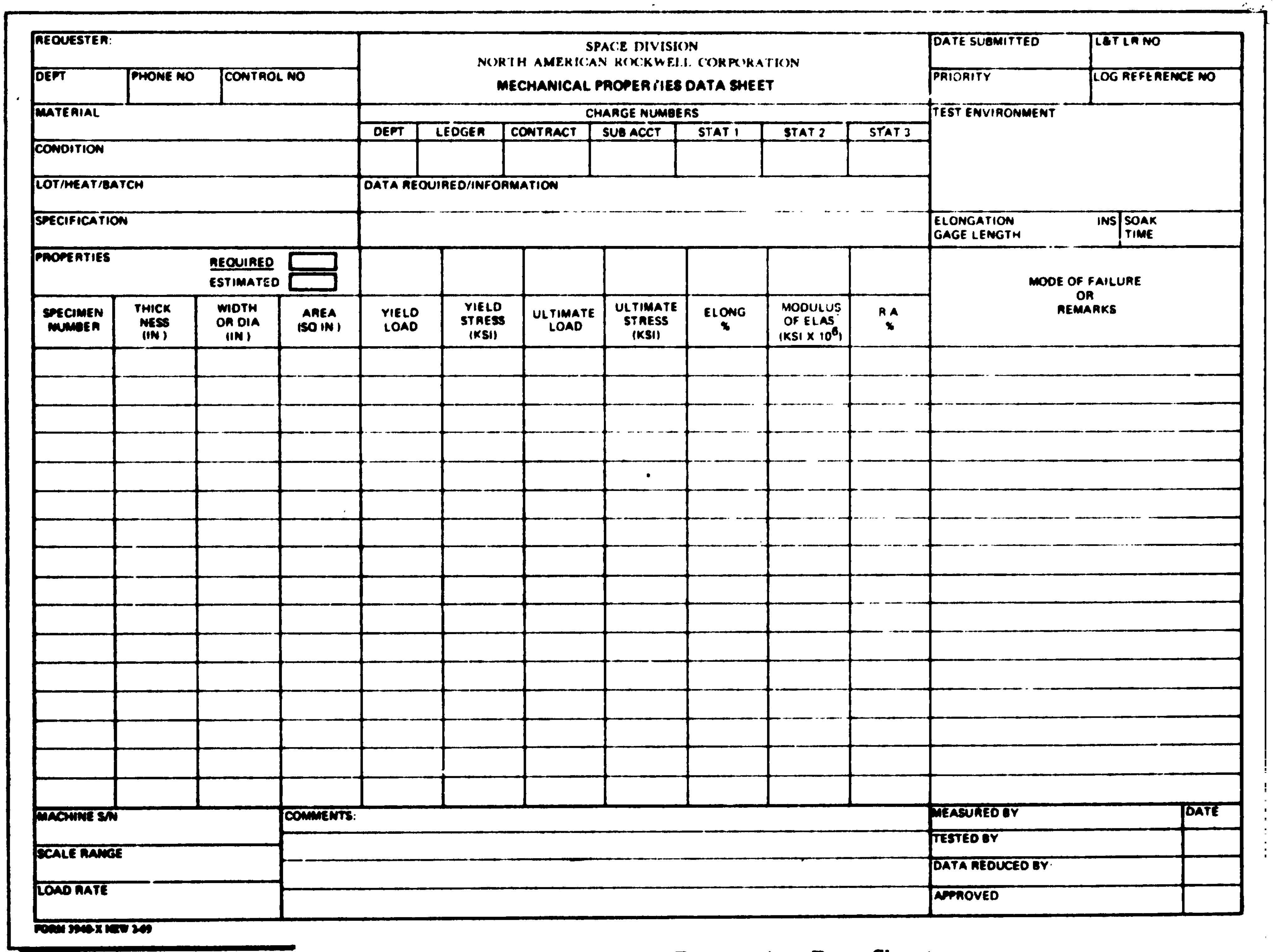
4. Butt welds involving overlapping welds (tie-ins), etc. At least two test sets comprising five tensile specimens each are selected; the weld start is located in the approximate center of one set of specimens, the weld stop in the approximate center of the remaining set.

	A	B MAX	C	D	E	F	G	H	J	K	L	M	N	P	FOR F_{TU} MAX. P.S.I.
-3	.750	.250	8.00	1.50	2.25	6.00	.500	1.00	3.00	4.00	1.13	.75	2.00	1.00	100,000
-5	.500	.500	8.00	1.50	2.25	6.00	.500	1.00	3.00	4.00	1.13	.75	2.00	1.00	100,000
-7	.750	.125	8.00	1.50	2.25	6.00	.500	1.00	3.00	4.00	1.13	.75	2.00	1.00	200,000
-9	.500	.250	8.00	1.50	2.25	6.00	.500	1.00	3.00	4.00	1.13	.75	2.00	1.00	200,000
-11	1.500	1.000	19.00	4.00	6.50	14.50	1.250	2.00	7.25	9.50	3.25	2.00	6.25	3.12	200,000



-11	COUPON		PER TEST	PER TEST 1.000 X 4.00 X 19.00	005
-9				PER TEST .250 X 1.50 X 8.00	004
-7				PER TEST .125 X 1.50 X 8.00	003
-5				PER TEST .500 X 1.50 X 8.00	002
L℄T STD. 0003 - 3	COUPON		PER TEST	PER TEST .250 X 1.50 X 8.00	001
PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA SPECIFICATION SIZES, NOTES, VENDORS	LINE NO.

Figure 3-1. Typical Fusion Weld Tensile Test Coupon



SPACE DIVISION
NORTH AMERICAN ROCKWELL CORPORATION
MECHANICAL PROPERTIES DATA SHEET

REQUESTER:			DATE SUBMITTED	L&T LR NO
DEPT	PHONE NO	CONTROL NO	PRIORITY	LOG REFERENCE NO

MATERIAL

CONDITION

LOT/HEAT/BATCH

SPECIFICATION

PROPERTIES — REQUIRED / ESTIMATED

CHARGE NUMBERS

DEPT	LEDGER	CONTRACT	SUB ACCT	STAT 1	STAT 2	STAT 3

DATA REQUIRED/INFORMATION

TEST ENVIRONMENT

ELONGATION GAGE LENGTH | INS | SOAK TIME

SPECIMEN NUMBER	THICK NESS (IN)	WIDTH OR DIA (IN)	AREA (SQ IN)	YIELD LOAD	YIELD STRESS (KSI)	ULTIMATE LOAD	ULTIMATE STRESS (KSI)	ELONG %	MODULUS OF ELAS (KSI X 10^6)	R A %	MODE OF FAILURE OR REMARKS

MACHINE S/N

SCALE RANGE

LOAD RATE

COMMENTS:

MEASURED BY	DATE
TESTED BY	
DATA REDUCED BY	
APPROVED	

FORM 3940-X NEW 3-69

Figure 3-2. Mechanical Properties Data Sheet

5. Complex butt welds involving tapered sections. A test shall include at least one tensile specimen from the maximum and one from the minimum section thicknesses.

6. Lap, fillet, edge, corner welds, and butt welds which are welded from both sides. One macro-section of each three test welds is visually examined for conformance to the applicable process specification.

7. Butt welds simulating each of the allowable supplemental weld operations. Welds must conform to Process Specification MA0107-016, Revision H.

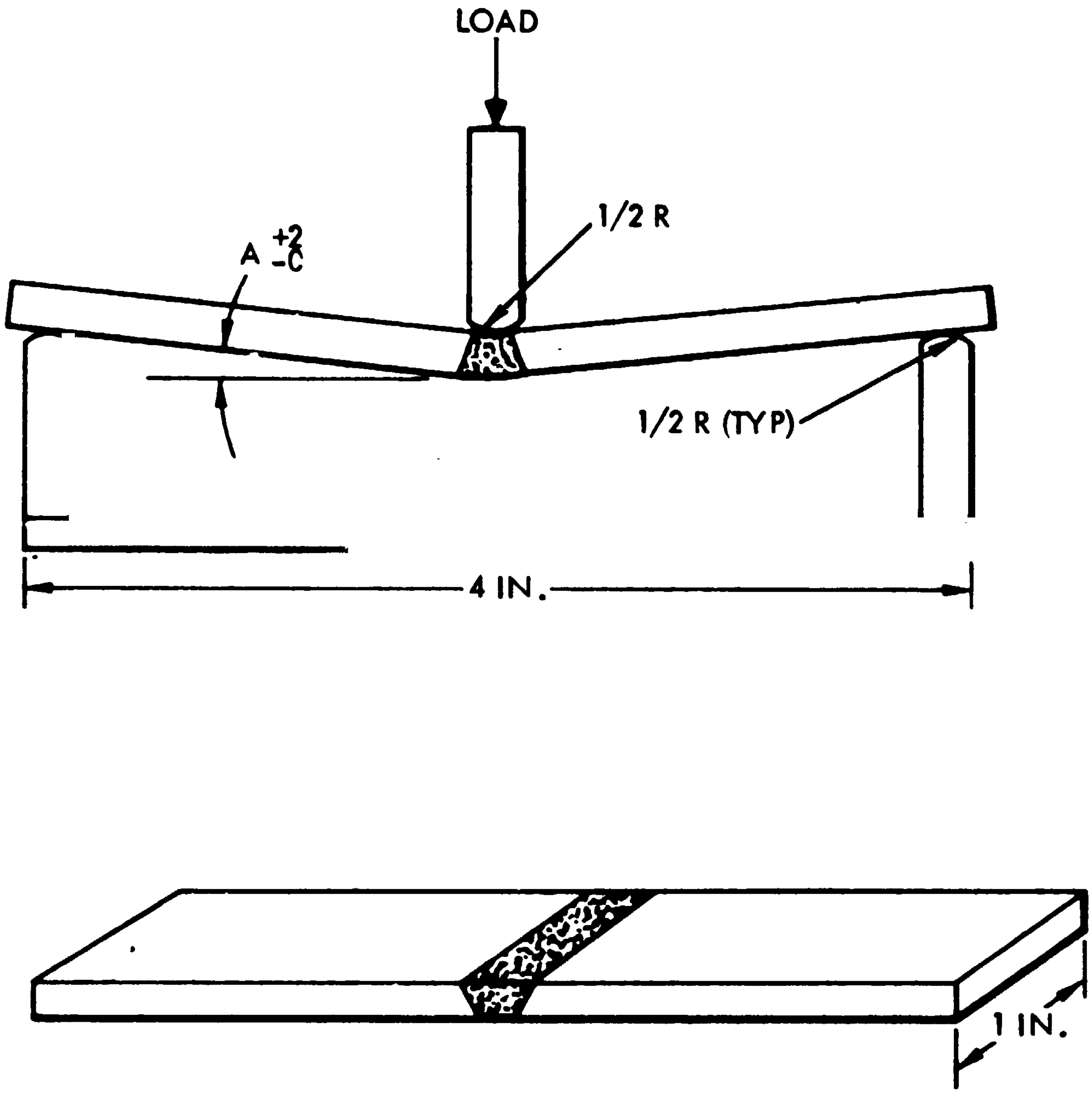
3.4 BEND SPECIMENS

A minimum of four bend test specimens comprise one test set. The individual specimens are cut from the certification test plate and machined to the configuration shown in Figure 3-3 for the following weld conditions. The dimensional measurement and test data are recorded on the type of form shown in Figure 3-2. The weld bead reinforcement must simulate the final configuration of the production weld. The bend test specimen is deflected to a permanent set at angle "a" $^{+2}_{-0}$ degrees. Figure 3-3 shows a root bend specimen being tested; the test specimen would be reversed if performing a face bend test. The weld area opposite the mandrel side of the specimen is examined for the presence or absence of rejectable defects. The bend specimens are not to be tested until a minimum of 36 hours natural aging after welding has elapsed. Cracks detected by visual or fluorescent penetrant inspections after testing are cause for rejection of the test weld specimen and certification for a production welding operation. Types of welds requiring bend tests are:

1. Butt welds in which the welding machine is stopped and restarted. The restart position is located in the approximate center of the bend bar specimen.

2. Butt welds involving overlapping welds (tie-ins), etc. At least two test sets comprising four bend specimens each are selected. The weld start is located in the approximate center of one set of specimens and the weld stop in the approximate center of the remaining set.

3. Complex butt welds involving tapered sections. A test shall include at least one bend specimen from the maximum and one from the minimum section thicknesses.



NOTE: MACHINE WELD FLUSH BOTH SIDES.
DEBURR ALL FOUR CORNERS.

Figure 3-3. Root Bend Specimen and Test Setup

4. Specimens taken from butt welds simulating each of the allowable supplemental weld operations listed in Process Specification MA0107-016, Revision H.

3.5 ORIGINAL MACHINE CERTIFICATION

Two 8-foot long panels are required for certification of primary welds associated with the LH_2 and LO_2 propellent tanks comprising the S-II vehicle. This encompasses all circumferential/girth and vertical cylinder splice welds contained in the primary structure. For each subsequent machine-weld unit added to the original certification, two 4-foot long panels are required. These are evaluated for conformance with the applicable process specification for welding. Figure 3-4 shows the location of all circumferential/girth welds on the Saturn S-II stage.

For certification of welds related to the aft LO_2, forward LH_2, forward-common, and aft-common bulkhead assemblies, two full-length panels simulating the meridian gore panels or dollar welds (as applicable) are welded. The certification panels for all types of welds described above are machined and tested to the following requirements:

The two welded panels must meet the quality requirements of MA0107-016, Revision H, for acceptance after visual, radiographic (X-ray), and fluorescent penetrant inspections. Removal of suspect fluorescent penetration indications in the weld is accomplished by abrading the excess weld joint metal to a level that is approximately flush with the surface of the parent metal. The panel is rejected if defects extending below the parent metal surface exceed the acceptance criteria defined in the applicable weld process specification.

NOTE:

(1) The certification weld panels are tested with the weld drop-through removed to within +0.005 and -0.000 inches from the parent metal (except for approximately 3 inches of weld near the throat of the J section on the forward common bulkhead assembly).

(2) The dollar section joint contained in the LO_2 bulkhead assembly which is welded from two sides utilizing the opposed-nugget method requires inspection by ultrasonic techniques in addition to those described above.

Five tensile strength and four bend-bar test specimens are machined from each full-length welded certification panel. The weld bead is transverse to the length of the test specimens. One tensile and one bend bar specimen

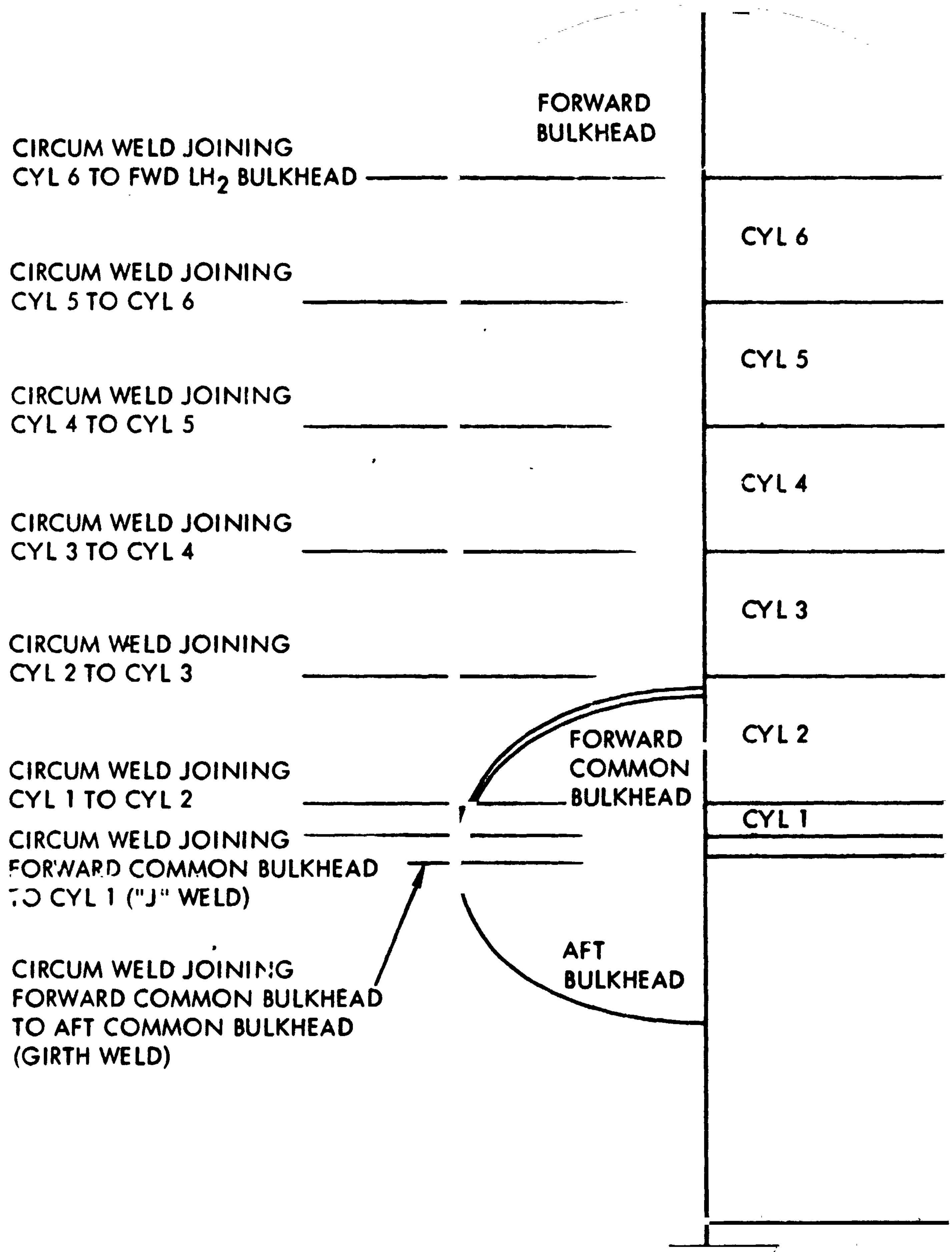


Figure 3-4. Saturn S-II Circumferential Welds

is removed for mechanical properties testing from both the maximum and minimum material thickness sections. The four bend-bar specimens are tested with the face side of the weld maintained in tension.

Five tensile and four bend-bar test specimens are machined from welded panels fabricated to simulate weld intersection or crossover zones as follows:

1. Three of the five tensile-bar specimens are machined from the test plate with the weld bead simulating the meridian or dollar weld located transverse to the length of the test specimen.

2. The two remaining tensile-bar specimens are machined from the test plate with the weld bead simulating the meridian or dollar weld located longitudinal to the length of the test specimens. All five tensile specimens are tested as described in paragraph 3.3.

3. Two of the four bend-bar specimens are machined from the test plate with the weld bead simulating meridian or dollar weld located in a position that is transverse to the bend bar.

4. The two remaining bend-bar specimens are machined from the test plate with the weld bead simulating the meridian or dollar weld located in a position that is longitudinal to the length of the bend bar. The four bend-bar specimens are then tested with the face side of the weld maintained in tension as described in paragraph 3.4.

NOTE: Horizontal crossover welds or weld intersections are machine-welded using the same parameters as defined in the applicable primary welding schedule. Requirements for welding horizontal crossover sections do not apply to the forward LH_2 bulkhead assembly.

Five tensile and four bend-bar test specimens are machined from the welded test plate. The specimens to be tested contain areas representing typical conditions where the machine was stopped and then restarted. The start/stop area is located in the approximate center of each test specimen. The five tensile specimens are tested as described in paragraph 3.3. The four bend-bar specimens are tested with the face side of the weld maintained in tension as described in paragraph 3.4.

3.6 SUPPLEMENTAL WELD OPERATIONS

Process Specification MA0107-016 permits one supplemental weld operation to correct any of the conditions listed below. These operations are contingent upon completeness and accuracy of the permanent records reflecting the actions pertaining to a given weld witnessed by Quality Assurance personnel. Quality data include the joint configuration prior to initiating corrective action, resulting joint configuration, welding parameters used, etc. Only one attempt to correct a deficient condition is permitted without prior Material Review Board (MR) authorization. Appropriate situations for such supplemental action include the presence in a weld of either:

1. Undercut
2. Lack of fill
3. Suckback
4. Incomplete penetration
5. Off-center weld nugget
6. Oxides and porosity needing repair which first must be exposed to the surface or removed by mechanically grooving or grinding. Heat passes to float out porosity and/or oxides are not permitted.

   NOTE: Any subsequent material review (MR) action, in an area of a supplemental weld pass, contains a description of the conditions under which the supplemental weld operation was performed.

3.7 TEST DATA

A copy of all destructive and nondestructive test data, including supplemental weld operations, is maintained by Quality Assurance and retained with the original copy of the applicable weld schedule. As other weld-machine power supply units are certified, the original weld schedule is amended to include their numbers and new test data.

3.8 FILLER WIRE ALLOYS

The filler wire alloys listed in Table 3-1 are applicable for welding only the corresponding aluminum alloys. The specific weld schedule must define the type, diameter, and deposition rate of filler wire alloy used for each weld pass.

Table 3-1. Types of Filler Wire Alloys Applicable for Welding Aluminum Alloys and Combinations of Alloys

Base Aluminum Alloy	2014 2024	2219	5052	6061
2014 2024	2319 4043 716			
2219	2319 4043 716	2319 4043		
5052	4043	4043	4043	
6061	4043	4043	4043	4043

NOTES: 1. Filler material is as specified in the applicable Form 971-D.
2. Filler alloys 716 and 4043 per QQ-R-566.
3. Filler alloy 2319 per MB0170-022.

The filler wire alloys tabulated in Table 3-1 are applicable for use with all S-II stage welds. Type 4043 filler wire is used for all welds except the aft LO_2 bulkhead dollar welds, the welds joining fill-and-drain ring to the LH_2 tank wall, the meridian welds on the forward-facing sheet section panels, and the welds joining the LH_2 feedline elbow ring to the LH_2 tank wall which are made using Type 2319 filler wire.

3.9 WELD JOINT STRENGTH REQUIREMENTS (BUTT WELDS)

Butt joints welded for certification and production welds must conform to the single-value minimum tensile strength requirements shown in Table 3-2. When dissimilar alloys are welded, the weld strength which pertains to the alloy having the lower weld strength determines the minimum requirement.

Butt welded joints, when subjected to bend tests, are capable of meeting the minimum deflection angles shown in Figure 3-5.

Table 3-2. Single-Value Minimum Strength Requirements for Butt Welds

Nominal Gage Thickness (inch)	Tensile Strength (ksi)		
	2014-T6 2014-T4	2024-T3 2219-T87 2219-T6	6061-0 6061-T4 6061-T6
Below 1/8	43	40	25
1/8 to 1/4	40	36	25
Above 1/4	38	36	20

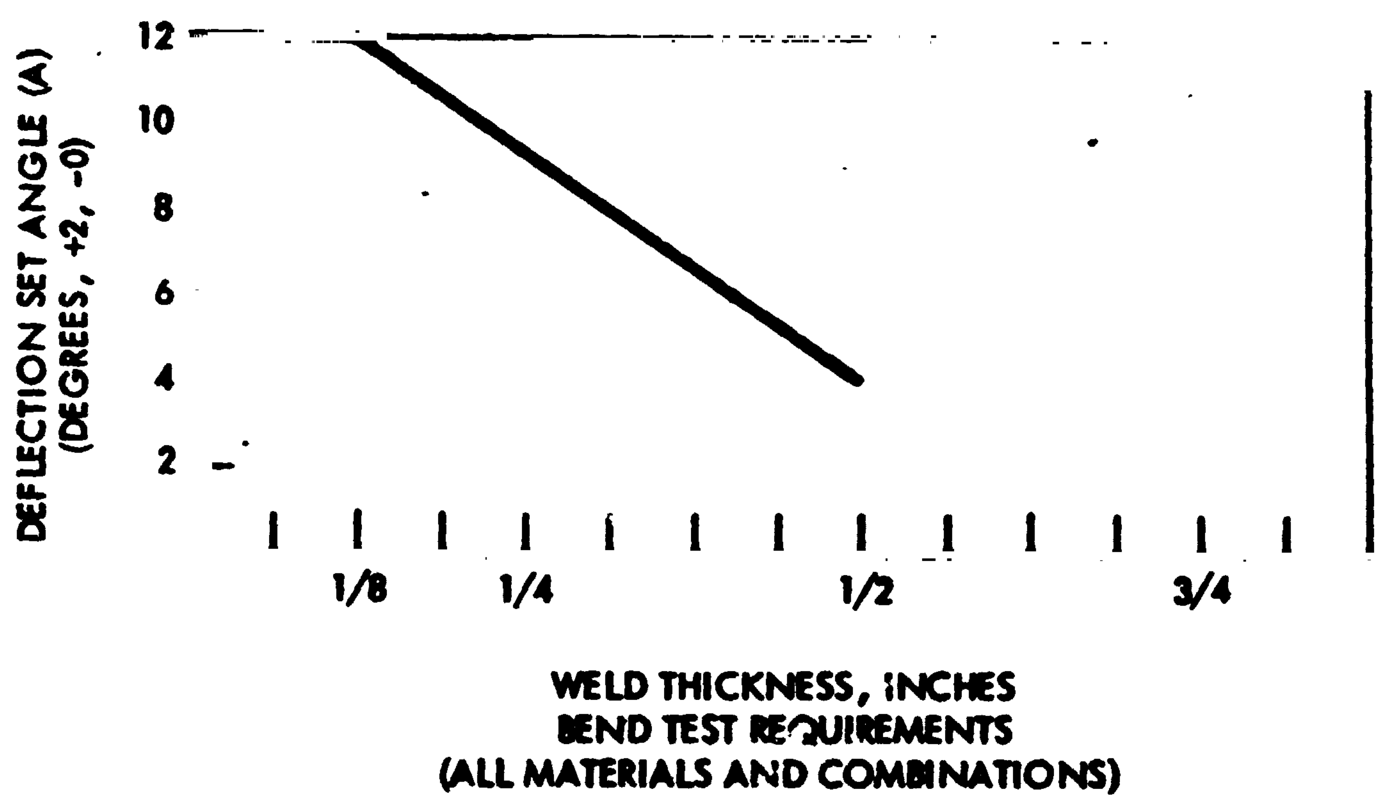


Figure 3-5. Minimum Bend Test Deflection Angle

3.10 WELD PARAMETERS

Verifying conformance to the permissible welding parameter variations (Table 3-3) are the responsibility c. the Quality Assurance representative. Departure from the approved welding schedule requires withholding the part, determination of the cause for departure, and corrective action before reinstating production welding with the same machine.

3.11 WELD SCHEDULES

A typical welding schedule and related detailed procedures are shown in Appendix B.

Table 3-3. Permissible Parameter Variations for Machine Welding

	Variation
Arc voltage	± 5 percent
Current	± 5 percent
Travel rate	± 10 percent
Wire feed rate	± 10 percent
Shielding gas flow - total	± 5 cubic feet per hour

4.0 PREWELD OPERATIONS

Quality Assurance is responsible for providing surveillance and technical support to assure compliance with all preweld operational requirements defined in the applicable process specifications and supplemental documents. This section describes the detailed requirements and procedures employed by the Quality Assurance organization in verifying operational conformance to these criteria.

4.1 GENERAL REQUIREMENTS

The determination that the equipment to be used is functioning properly and that preweld cleaning has been satisfactorily accomplished on the faying and adjacent surfaces of a joint to be welded is the responsibility of both Manufacturing and Quality Assurance personnel. The basic requirements for control of material and weld test certification and verification procedures and for cleanliness control operations are provided in Reference 4-1; more detailed cleaning requirements are specified in the applicable welding schedule (Form 971-D). The control of preweld cleaning operations is extremely critical as the resultant weld quality (amount of internal and surface discontinuities) is directly related to how well the weld joint edges and faying surfaces were cleaned before commencing the welding sequence.

The adequacy of preweld cleaning is not determined by visual inspection techniques only. Other quantitative and nonquantitative verification methods are used to determine conformance to total operational cleanliness requirements. For example, Quality Assurance verifies each of the cleaning sequences as it occurs, and assures that all persons who clean the parts, equipment, devices, and tooling, and those who use the mechanical measuring devices after cleaning, wear clean, lint-free smocks or coveralls and gloves, and use only the appropriate types of wiping cloth.

Quality Assurance personnel assure that the following operations have been completed through surveillance of the cleaning procedures:

1. Removal of oil or other contaminants from tools and the weld joint with acetone or MEK solvents as applicable.

2. Removal of coatings using an acceptable abrasive, solvent, or stripper.

3. Removal of surface metal adjacent to the projected weld joint centerline with a scraper or draw file for a minimum distance measuring 0.50 inch.

4. Removal by scraping or draw-filing of any contaminant generated during previous cutting or trimming operations.

5. Removal of the residue from scraping or draw-filing operations by vacuuming.

The cleaning steps specified in the applicable weld schedule (Form 971-D) have been developed to assure the maximum probability for attaining an acceptable weld joint. The order of these sequential operations as well as adherence to the instructions for cleaning after tack welding or between weld passes are important factors which affect the quality of the weld. In essence, "on-the-spot" surveillance to assure that each cleaning operation has been performed adequately and in a timely manner has proved to be the best technique to evaluate the effectiveness of preweld cleaning.

The test requirements described in this section are used as the basis for a checkoff procedure that must be completed before initiating any welding sequence. It is therefore incumbent upon the responsible Manufacturing area supervisor to notify supporting organization personnel in sufficient time for them to do their job. This means the area supervisor must be familiar with the time needed by support activities so that the work can be planned in the most efficient manner. Conversely, supporting group personnel must also be aware of the Manufacturing work schedule and plan their work accordingly to provide support when it is needed.

The preweld preparation plan used to verify weld equipment, material, tooling status, and total preweld cleanliness is described in the following paragraphs.

4.2 WELDING EQUIPMENT

All welding machines must conform to the operational requirements of Process Specification MA0107-016 or MA0607-017. Each welding machine must be certified to be capable of satisfactorily welding the specified joint at a given material thickness. If three pieces of welding equipment are to be used in making a production weld, all three units must be certified. The applicable certification schedule for each weld must be posted on or near the machine at all times.

The Sanborn brush recording instruments associated with each weld pack must be calibrated and in operating condition. The recording instruments must be used during all types of reportable welding situations, such as certification welds, verification welds, production welds, and repair welds in stations at which recorders are used. If for any valid reason the recorders are not available (one recording instrument for each piece of weld equipment is required), Quality Assurance personnel will visually observe weld package control instruments and document data related to the minimum and maximum weld voltage attained, skate travel, wire feed, and current employed during a given weld sequence. In addition, the location on a weld must be identified (as closely as possible) in the event an out-of-tolerance condition occurs.

4.3 WELD TESTS (FUNCTIONAL)

Verification Weld Test Plates

The testing and evaluation of butt-joint verification welds is the responsibility of Quality Assurance as specified in Process Specification MA0107-016 (Reference 4-1). Verification weld tests are performed before initiating a primary production welding sequence to demonstrate the capability of the designated welding equipment, associated tooling, and the previously developed welding schedule to continue producing acceptable production welds.

Verificat n butt-welds are required for each circumferential LH_2 and LO_2 tank weld and for other stage welds only when at least one of the following conditions exist.

1. Welding equipment has been relocated or a major equipment component has been repaired.

2. Holddown fixtures, backup bars, or the mold-line contour of the tool have been reworked.

3. Defects occurring on repetitive basis in a specific weld area or type of weld.

A verification butt-weld will be made using each welding machine involved in the production weld. The weld will be a minimum of three feet in length and will be fabricated using material that is the same alloy, heat treat condition, and thickness as the production part or assembly. The welding parameters and conditions will be exactly as those specified on the welding schedule (971-D) for the production weld being evaluated. For weld joints involving thickness changes, however, two uniform-thickness verification test welds will be utilized to represent the minimum and the maximum thickness conditions of the production weld. These will be welded at the applicable parameters for these conditions as set forth in the appropriate welding schedule. For circular or circumferential weld joints, the verification weld may be a straight weld but must conform to all other verification weld requirements.

Verification butt-welds will be evaluated for conformance to the postweld dimensional, radiographic, and surface quality requirements as specified in the applicable sections of MA0107-016.

Surface discrepancies detected by fluorescent penetrant inspection may be mechanically abraided flush to the parent metal surface. The panels will be rejected if the defects exceeding the allowables of Process Specification MA0107-016 extend below the parent metal surface.

Bead-on-Plate Standard

A bead-on-plate standard is welded and maintained for each weld certification. Before each production weld, a bead-on-plate weld will be made and compared with the standard to determine adequacy of gas coverage, gas purity, operating condition of the welding machine, and repeatability of bead geometry. Material for each bead-on-plate weld will be of the same alloy, heat treat condition, and geometry as the original standard.

Where controls for tapering or varying thickness welds are used, the preweld bead-on-plate will be made within the range of parameters to be used for the production parts, including the maximum and minimum parameters associated with material thickness variations.

4.4 ACCESSORY TOOL CLEANING AND CONTROL REQUIREMENTS

To control the quality of welding, the cleanliness of accessory tooling (i.e., NASA clamps, stainless steel straps, wire spacers, draw files, etc.) must be closely controlled. The following procedure is used to remove such shop contaminates as oil, grease, fingerprints, and dirt from accessory tooling. NASA clamps should be disassembled before cleaning and reassembled without lubrication. Tool cleaning follows this sequence:

1. Clean each item by wiping with MEK or acetone and vapor degrease per Process Specification AA0110-002 (Reference 4-2).

2. Clean each item ultrasonically per Process Specification MA0110-017, Table II or Table III (Reference 4-3).

3. Package NASA clamps individually and stainless steel straps and wire spacers in groups of 10 by heat-sealing polyethylene bags conforming to Federal Specification L-P-378, Type II, Grade B, Finish 1 (Reference 4-4) and maintain Cleanliness Level 3, Material Specification MB0295-005 (Reference 4-5).

NASA clamps used in the weld prefit operation and which will again be used during welding will be repackaged without recleaning if free from visible contamination. After completion of each weld, the NASA clamps are to be recleaned and repackaged. The stainless steel straps and wire spacers are discarded after use. All personnel handling welding implements will wear clean cotton or nylon gloves (or equivalent) conforming to MRO Standard MM8415-002 (Reference 4-6).

4.5 MATERIAL CONTROL REQUIREMENTS

Filler Wire Alloys

The welding filler wire is inspected for proper identification (alloy, size, lot number, etc.). The outer layer of wire is removed from each new spool before loading it into the welding machine. The roll of material will be identified and retained by Quality Assurance in the event a post-weld metallurgical evaluation of the filler wire is required. The welding wire must not be handled except by personnel wearing clean nylon or cotton gloves. The newly exposed outer layer of filler wire is examined visually for evidence of excessive scoring, nicks, or contamination before use on a production weld.

Parent Metal

The trim remnants from each quarter panel, J section, and bulkhead gore segment is submitted to Quality Assurance after completing the mechanical cutting and trimming operations. These aluminum alloy material samples are retained until final quality acceptance of each weld is provided. Each sample of trim remnant is identified with respect to location, part number, part serial number, end-item assembly or vehicle number, etc.

Electrodes (Tungsten)

Before initiating each welding sequence, the Quality Assurance representative must verify that the tungsten electrodes required for each specific weld reflect the configuration specified on the applicable primary welding schedule (Form 971-D). The procedures for configuration identification and configuration control of tungsten welding electrodes used on the Saturn S-II program are described in the following paragraphs.

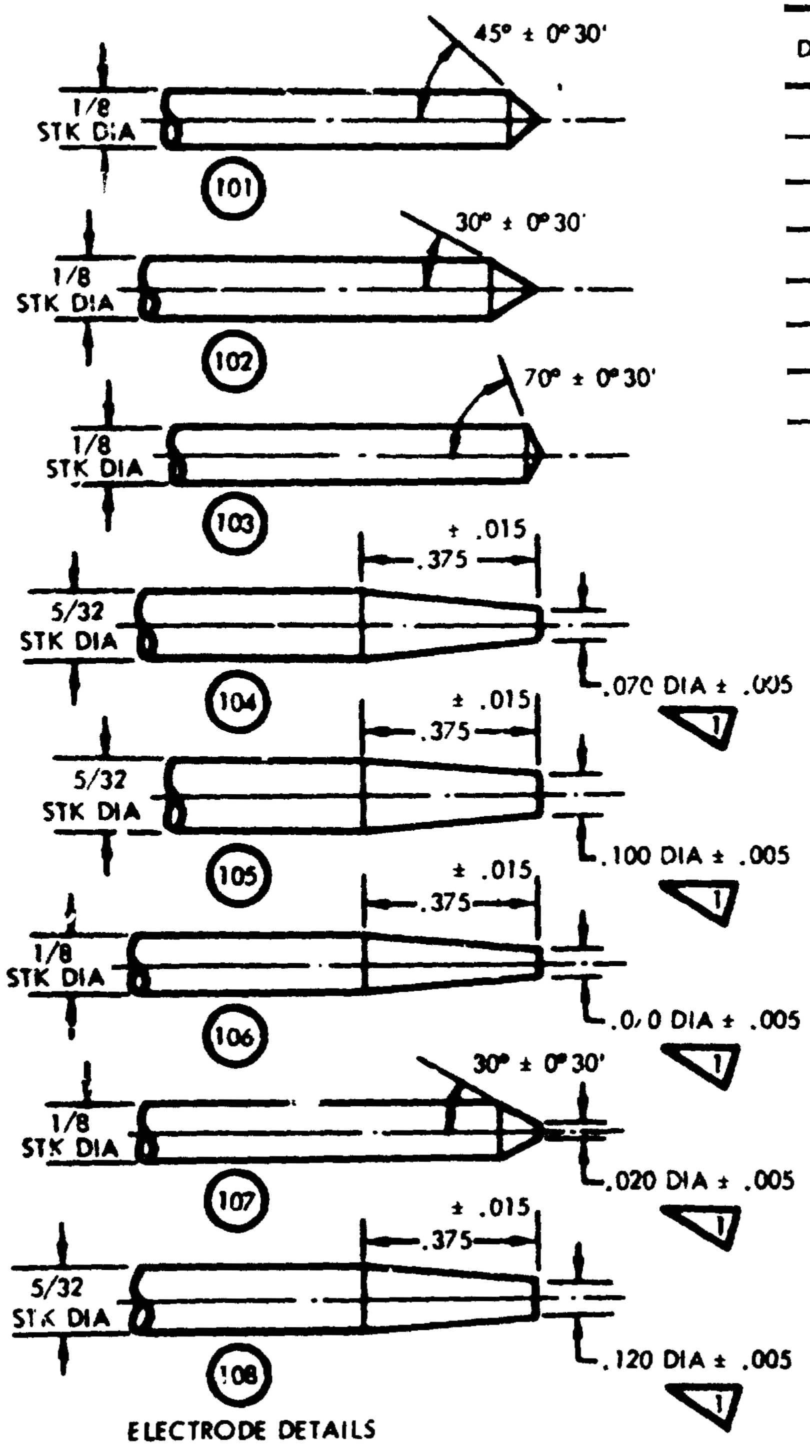
Figure 4-1 depicts the tungsten electrode shapes used for welding on the Saturn S-II Program and defines the method of identification to be employed. The applicable welding schedule (Form 971-D) specifies the tungsten electrode tip configuration to be used for the varying types of welds utilized. The electrodes are identified on each weld schedule by a sketch which details the actual electrode configuration and references the SK drawing number which corresponds to the applicable electrode shown in Figure 4-1. Stock (or blank) welding electrodes are procured by Manufacturing using standard procurement practices.

Machining of the tungsten electrode tips is accomplished by submitting blank tungsten electrode stock, protective vinyl envelopes, and identification labels to the Manufacturing machine shop with an internal letter (IL) describing the operation to be performed. The protective vinly envelopes and identification labels used for electrode storage are shown in Figure 4-1. The IL notes the quantities and configurations required for each group of electrodes and references the applicable drawing code number. After the machining operation, the responsible Quality Assurance representative inspects each machined electrode to the configuration requirements defined in the referenced SK drawing as instructed in the IL issued by the using manufacturing department. When judged acceptable, the electrode configuration number is entered on the identification label (SK 017352-110), affixed with an inspection acceptance stamp, and inserted in the vinyl protective envelope (SK 017352-109) which is folded and stapled closed as illustrated. The envelopes containing the verified tungsten electrodes are returned to the originating Manufacturing department for use. Expended tungsten welding electrodes are processed in the same manner or discarded when machining is no longer practical.

Shielding and Purge Gas

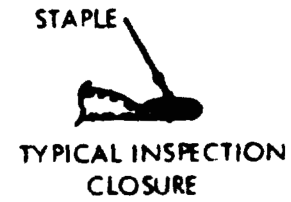
All inert gas used in the welding operation — whether it be for shielding, purging, or used to blow off filings or foreign particles on weld lands — is checked by the laboratory prior to performing production or verification welds, to verify that the gas purity and moisture content conforms to the requirements shown in Table 4-1. Shielding gas used on each welding machine is tested by obtaining a sample from the weld torch (Figure 4-2). Removing the gas sample from the weld torch not only verifies the purity of the gas supply, but also the purity of gas contained in the complete line system (e.g., from the K bottle gas supply, through the welding unit, and out the weld torch). Each verified gas supply line system is to be purged from the weld torch-head for a minimum of 15 minutes before initiating a weld sequence.

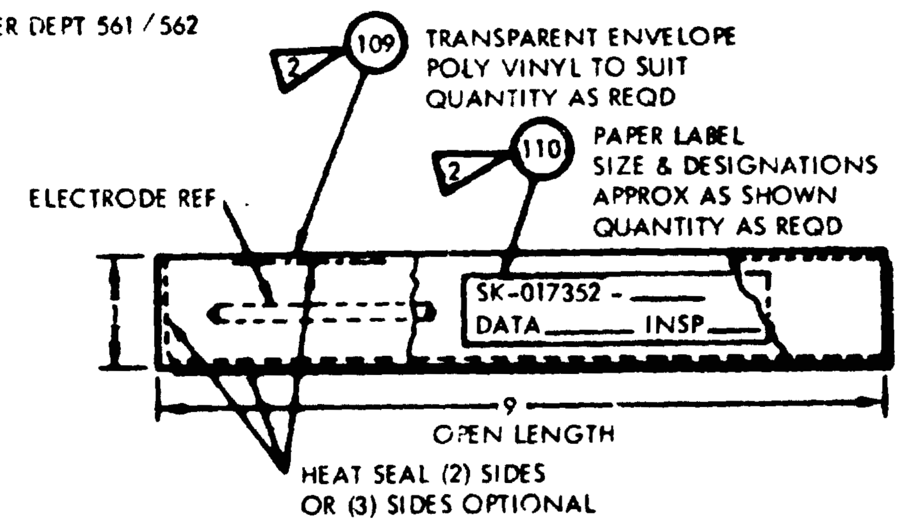
Newly installed manifold systems are not allowed to be used for any production welds until verified by Quality Assurance to be capable of supplying gas at the purity levels defined in Table 4-1.



DETAIL	QUANTITY	SIZE (3)	ELECTRODE
-101		1/8 DIA X 7	2% THORIATED TUNGSTEN (PER MA0107-016)
-102		1/8 DIA X 7	
-103		1/8 DIA X 7	
-104		5/32 DIA X 7	
-105		5/32 DIA X 7	
-106		1/8 DIA X 7	
-107		1/8 DIA X 7	
-108		5/32 DIA X 7	

PER DEPT 561 / 562





NOTES

1. NOTED DIAMETERS TO BE CONCENTRIC WITH & WITHIN .005 T.I.R.
2. -109 ENVELOPES & -110 LABELS TO BE ORDERED FROM D-071 BY I.L. (SPECIFY QUANTITY & CHARGE NUMBERS)
3. ELECTRODES MAY BE SALVAGED BY REGRINDING TO MIN LENGTH OF 4 IN.
4. ALL GRINDING TO BE "DRY" (TO AVOID CONTAMINATION)
5. DEPT 148 IS TO COMPLETE LABEL INFO AND ENCLOSE ELECTRODE & LABEL IN INDIVIDUAL ENVELOPE & STAPLE APPROX AS SHOWN
6. MACHINED SURFACES TO BE 62 MAX

Figure 4-1. Saturn S-II Welding Electrode Configurations

Table 4-1. Analysis Requirements for Weld Gas
(Measured at Weld Torch)

Type of Test	Requirements*
Hydrocarbon	5 ppm (max.)
Oxygen	10 ppm (max.)
Moisture	20 ppm (max.)
Total impurities including nitrogen	50 ppm (max.)

*These are arbitrary requirements established by Quality Assurance (and concurred in by Manufacturing) for verifying cleanliness of the gas supply contained in the line system and measured at the torch, rather than specification requirements defined for the gas supply contained in the K bottle source.

4.6 WELD STATION ENVIRONMENTAL AND CLEANINESS CONTROL REQUIREMENTS

Cleaning Requirements - Weld Stations

All preweld cleaning operations are conducted according to process specification. Additional cleaning procedures were added by Quality Assurance and Manufacturing to eliminate almost any possibility of weld defects related to improper cleaning or lack of control. In addition to the requirements previously listed, the following steps are performed:

1. All cabinet tops, tooling, building support beams, fixtures, etc., are vacuum cleaned or dusted to reduce possible contaminants. Walls are cleaned as required (i.e., when dirt, dust, chips, etc., are visually observed).

2. The weld station floors are wet-mopped; this is done on the shift prior to the start of the preweld cleaning operation.

Environmental Controls - Weld Stations

The following temperature and humidity requirements in all weld stations are established and controlled by Manufacturing:

Temperature - 74 F minimum, 80 F maximum

Relative humidity - not to exceed a maximum of 50 percent

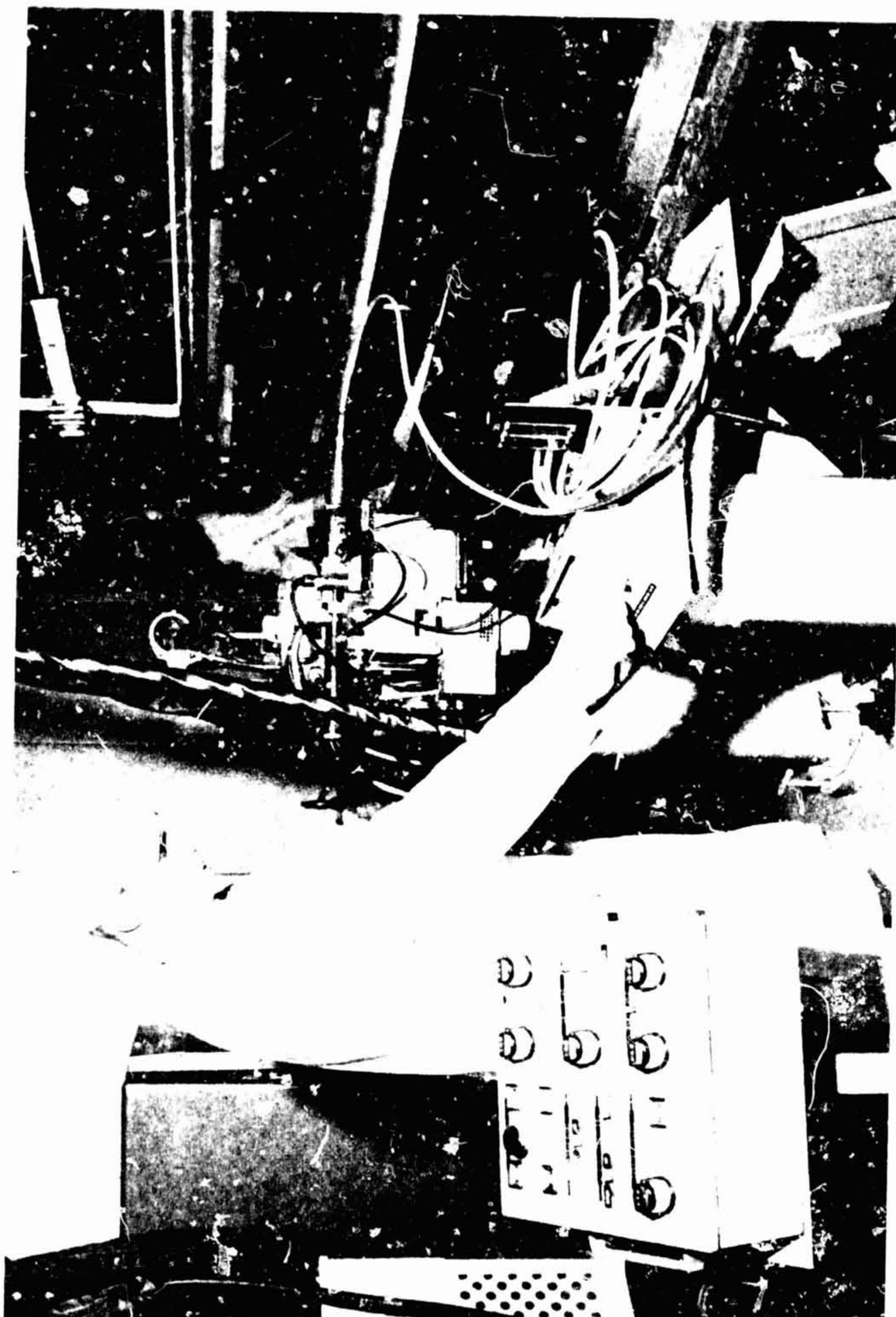


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Figure 4-2. Equipment Used to Check Moisture Content of Weld Shielding Gas

4.7 PREWELD JOINT CLEANING PROCEDURES

Solvent Wiping

As previously stated, all preweld cleaning sequences are clean-glove operations. In addition, clean, lint-free coats and caps are worn during the final cleaning operations. This is done to assure that no organic particles or residues (including lint, fingerprints, etc.) contact the weld surface.

Acetone is the cleaning fluid used on weld surfaces to remove organic contaminants such as oils, grease, fingerprints, etc. The cleaning procedure is as follows:

1. Fold clean cheesecloth into pads and dampen with clean acetone. Do not saturate the cheesecloth with solvent.

2. Wipe the weld-joint surfaces with acetone-dampened cheesecloth. The cloth is folded over the butt surface so that the inboard and outboard surfaces, as well as the butt surfaces of the material, are wiped simultaneously. Do not wet the weld joint surface with solvent.

3. Rub hard enough to remove tape residues, oils, dirt, fingerprints, etc. from the affected zones.

4. Change cheesecloth frequently so that existing contaminants are not smeared into or along the areas of the weld joint.

Abrasion Cleaning of Metal Adjacent to Weld Joint

An area approximately two inches in each direction from the weld centerline on the inboard and outboard well-joint surfaces (where possible) are polished with a Bear-Tex wheel for the full length of the weld. The Bear-Tex operation is performed by chucking a Bear-Tex wheel measuring 4 inches in diameter and 1 inch in width into an air motor. Extreme pressure on the Bear-Tex wheel must be avoided to prevent excessive material removal in localized areas. The butt faces of the weld joint must not be polished with the Bear-Tex wheel. The entire weld area is to be vacuumed after completion of the Bear-Tex operation.

Draw File Preparation of Weld Joint

The preweld joint cleaning process is basically a draw-file operation. Vixen-type draw files and stainless steel wire brushes are precleaned as previously described in the Accessory Tool Cleaning Procedure section.

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Draw File Preparation of Weld Joint

The preweld joint cleaning process is basically a draw-file operation. Vixen-type draw files and stainless steel wire brushes are precleaned as previously described in the Accessory Tool Cleaning Procedure section.

Metallic chips are brushed from the teeth of the vixen file during use with a clean stainless steel brush. Precleaned files and brushes are protected with aluminum foil. The wire brushes must be either cleaned in-process with fresh acetone and dried or discarded when any metallic contamination is detected. Only qualified and trained personnel are allowed to perform the draw filing operation on production hardware. Draw filing is permitted in one direction only; the file may never be dragged back across a previously cleaned area. Local surface pockets or zones which are difficult to clean with the file may be cleaned with a Manufacturing-approved scraper, but it also may cut in only one direction. Upon completion of draw filing the inboard and outboard weld surfaces (Figures 4-3 and 4-4), all chips and filings are removed by vacuuming.

The butt faces (or mating surfaces) of the weld joint are then draw filed. In cleaning the butt faces, the vixen file must lie flat on the surface to prevent the occurence of irregular surfaces when finished. Next, the inboard and outboard corners of the butt weld joint are beveled as shown in Figure 4-5. The bevel is a 45-degree angle, maintained within 1/32 inch (minimum) to 1/16 inch (maximum).

Quality Assurance must monitor and visually inspect the surfaces prepared by filling to assure there are no burrs machine tool marks, pits, or Chem-film residues present and that the cleaned surfaces have a bright appearance. The complete weld area, including tooling, is again vacuumed to remove all loose material.

Ultraviolet "Black Light" Inspection of Weld Joint

An inspection team consisting of Manufacturing and Quality Assurance personnel then examines the entire weld joint zone with an ultraviolet or "black light" as shown in Figure 4-6. During this inspection all normal lighting is reduced to the minimum level possible. The entire weld area is scanned for indications of contamination which "fluoresces," such as lint and organic particles or smears. Any contamination visually detected in this manner is removed by vacuuming or light brushing with a clean stainless steel wire brush. The vacuum hose must not be allowed to come in contact with the cleaned surface. To prevent this the vacuum nozzle is protected with clean cheesecloth.

If the interval between cleaning and welding is expected to exceed two hours, the cleaned surfaces are protected by aluminum foil. If the cleaned surfaces become contaminated, the entire cleaning cycle must be repeated. During the actual welding operation, the "black light" inspection is performed to assure that floating particles do not settle in or immediately adjacent to the joint to be welded.

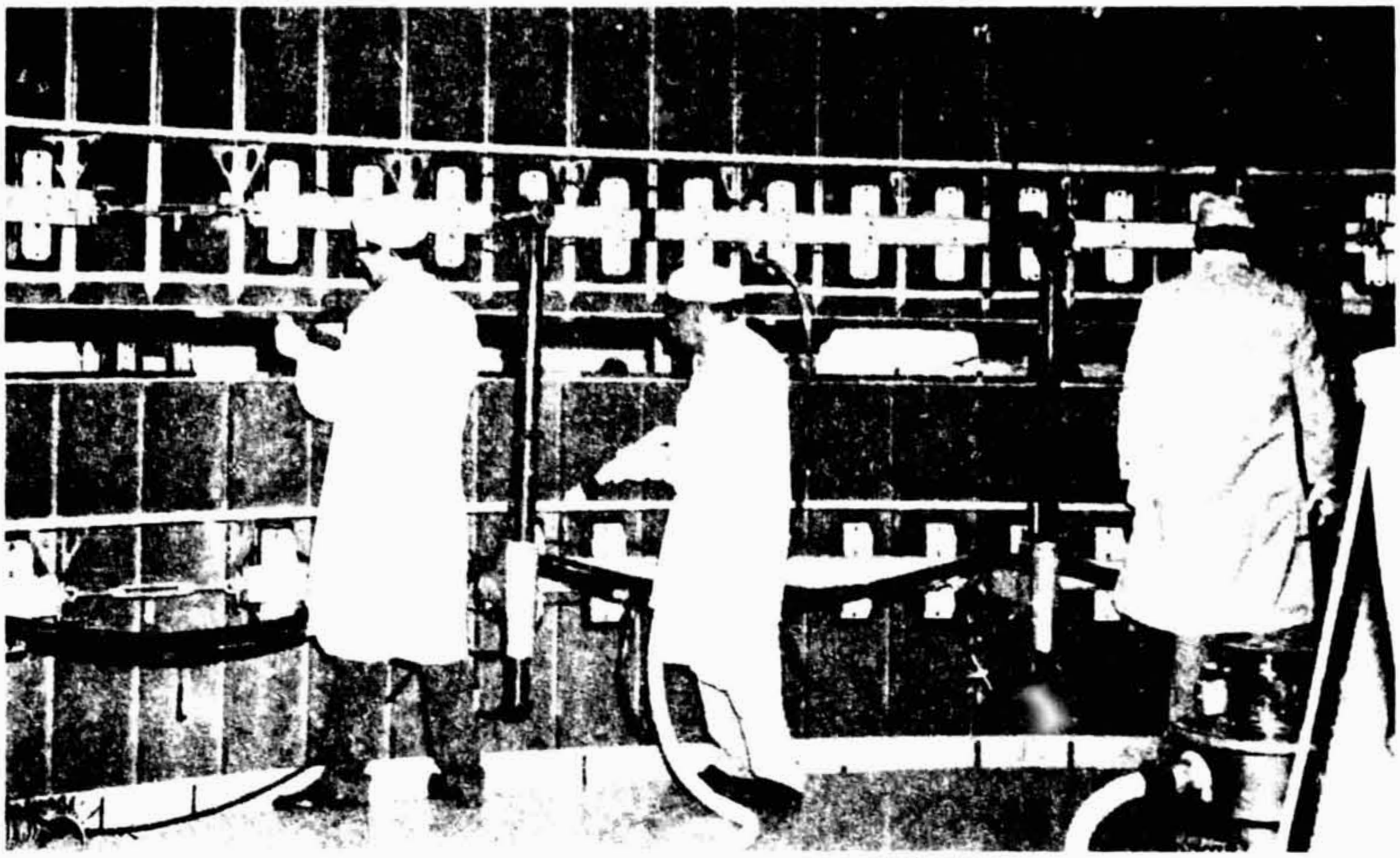

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Figure 4-3. Draw-File Cleaning of Inboard Weld Surface

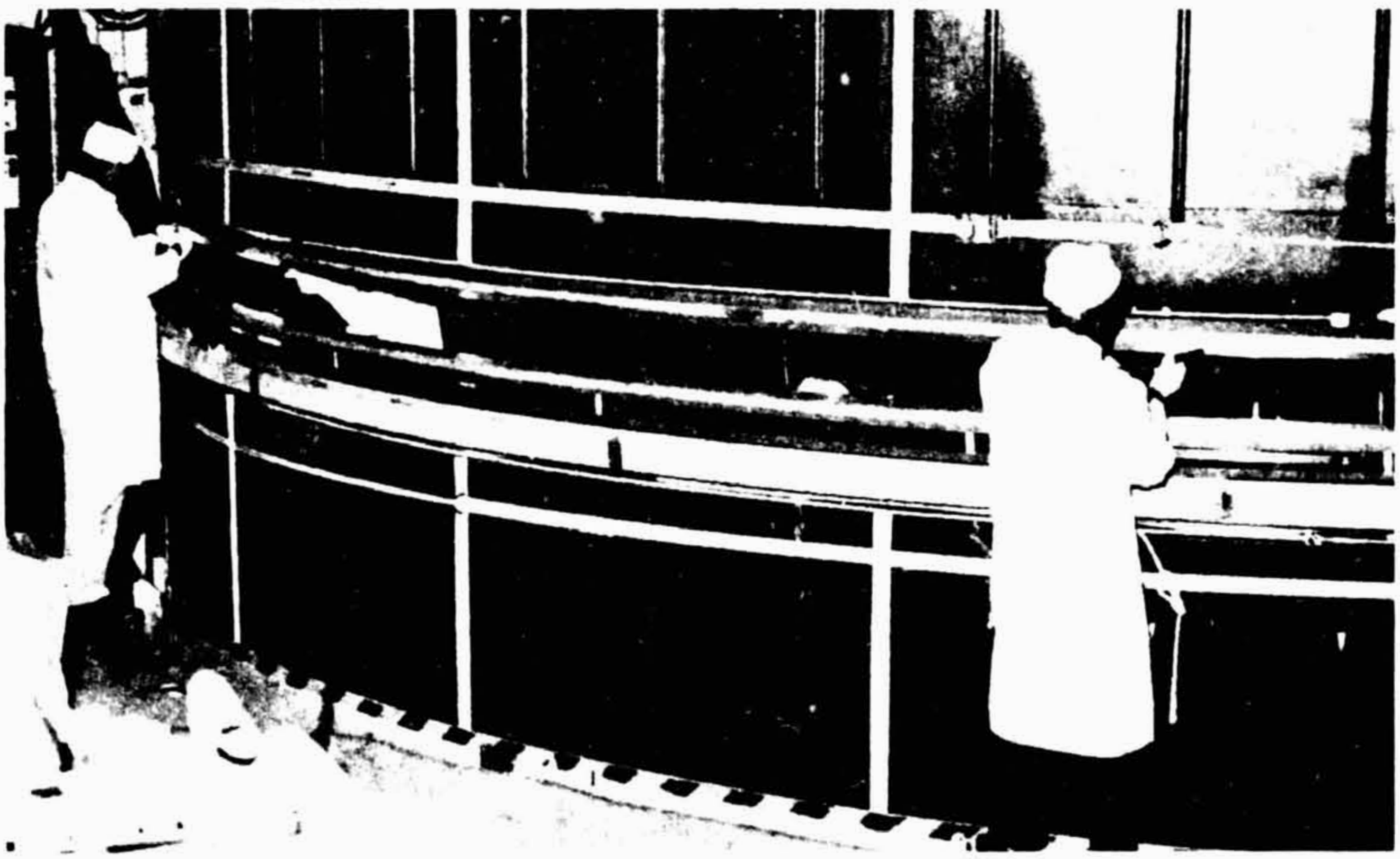

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Figure 4-4. Draw File Cleaning of Outboard Weld Surface

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Figure 4-5. Draw Filing to Produce Weld-Joint Chamfer

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Figure 4-6. Ultraviolet Black Light Inspection

4.8 PREWELD INSPECTION REQUIREMENTS

Inspection Checkpoints

The following sequence will be followed before proceeding with the production welding sequence:

1. Record the temperature and relative humidity readings obtained immediately prior to production welding.

2. Check and record gap and offset readings for conformance to the requirements listed in Process Specification MA0107-016.

3. Check all machine weld settings against the established parameters listed in the applicable 971-D weld schedule.

4. Check the amount of inert gas in the line system to assure that the supply is sufficient to complete a given welding sequence.

5. Verify that each welding torch is purged for a minimum of 15 minutes before initiating a given welding sequence.

6. Check to assure that ground and signal cables are properly attached.

7. Check all electrical cables to assure proper attachment.

8. Check the amount of weld wire on each spool to assure that there is a sufficient supply to complete a given welding sequence.

9. Verify that no tape has been placed on the weld joint or the areas immediately adjacent to the weld joint.

10. Record the atmospheric particle count immediately prior to (and during) the welding operation, as requested by Quality Assurance.

11. Verify satisfactory examination of the weld joint by "black light" inspection.

12. Verify the complete acceptance of the verification weld panels.

Inspection Concurrence for Approval to Weld

Providing all of the items listed in the preceding subsections have been satisfactorily verified, Quality Assurance provides concurrence for

Manufacturing to perform preweld tests. This test consists of the bead-on plate weld which was previously described. If the bead-on plate weld deposit is determined to be satisfactory, the "OK to weld" is given. Operations on the preduction weld should commence within five hours after final cleaning has been completed.

4.9 PRODUCTION WELDING REQUIREMENTS

Quality Assurance monitors all functions during the actual production welding sequence to assure compliance to the requirements of Process Specification MA0107-016. The detailed Weld Analysis Data Sheets (Figure 4-7) will be maintained during welding and all data pertinent to the process recorded. Any deviations from Process Specification MA0107-016, either during production welding or post-weld inspection, will be recorded in the appropriate FAIR book.

4.10 REFERENCES

4-1. NR/SD Process Specification MA0107-016: Machine Fusion Welding of Aluminum Alloys for Saturn S-II Vehicle.

4-2. NR/SD Process Specification AA0110-002: Solvent Vapor Degreasing.

4-3. NR/SD Process Specification MA0110-017: Ultrasonic Cleaning.

4-4. Federal Specification L-P-378: Polyethylene.

4-5. NR/SD Material Specification MB0295-005: Material Cleanliness Levels, Precision Clean Packaging.

4-6. NR/SD MRO Standard MM8415-002: Garments and Accessories for Environmentally Controlled Areas.

DETAILED WELD ANALYSIS DATA SHEET

Vehicle ________. Weld being made ________. Weld power supply No. ________.

and ________. Weld schedule No. ________ Revision No. ________ Final weld cleaning

started, data and time ________. Completed, data and time ________.

Building, floor and station weld made ________.

TACK WELDING

Data and time intermittent tack welding started ________. Completed ________.

Data and time cover tack weld started ________. Completed ________.

Power supply No. ________ Tacked from position ________ to position ________.

Power supply No. ________ Tacked from position ________ to position ________.

Difficulties encountered during tack welding ________.

Target offset dimensions for post-weld tacking ________.

PENETRATION PASS

Data and time penetration pass started ________ Completed ________.

Power supply No. ________ Penetrated from position ________ to position ________.

Power supply No. ________ Penetrated from position ________ to position ________.

X-Ray Control No. ________ No. views withheld ________ MRD Number ________.

Number views reworked ________ Total inches repaired ________.

Document rework welded to MRD or in Process ________ Weld schedule ________.

Total No. of views withheld, including defect types, size and location: ________.

COVER PASS

Data & time first cover pass started ________ Completed ________ Second cover pass

Started ________ Completed ________ First cover pass: power supply No. ________.

Used from position ________ to position ________ power supply No. ________.

Used from position ________ to position ________ Second cover pass: power supply

No. ________ used from position ________ to position ________, power supply No. ________.

Used from position ________ to position ________ X-Ray Control No. ________.

No. of views withheld ________ MRD No. ________ No. of views repaired ________.

Total inches repaired ________ Weld repair schedule ________ X-Ray View No's. repaired ________.

Total No. of views withheld, including defect type, size and location: ________

____

Figure 4-7. Detailed Weld Analysis Data Sheet

5.0 IN-PROCESS AND POST-WELD OPERATIONS

Quality Assurance is responsible for assuring compliance with all of the in-process and post-weld requirements of the applicable process specifications and related supplemental documents. This section describes the methods used to assure conformance with in-process and post-weld quality criteria.

5.1 GENERAL REQUIREMENTS

During welding operations, the Quality Assurance representative assures that all requirements listed in the applicable welding schedule (Form 971-D) and the applicable process specifications are followed. The function of the Quality Assurance representative during the conduct of a Saturn S-II circumferential welding operation is described in this section.

5.2 TACK WELDING

The Quality Assurance representative verifies that the required Sanborn recording devices described in Section 4.0 are energized and operable during all tack welding sequences. Manufacturing weld engineers or production personnel measure the amount of pre-tack weld-joint offset (see Figure 5-1) and instruct the welder in recording the location and time required to deposit each tack weld. Quality Assurance personnel record on Detailed Weld Analysis Data Sheets, the date and time the tack weld sequence is initiated and completed. Also recorded are data pertaining to the quadrant areas or linear zones tacked by each welding machine.

Immediately after each tack weld is deposited, the Quality Assurance representative measures and records the amount of post tack-weld offset incurred (if any) and the location of each offset reading. A precleaned dial caliper is used to measure the post tack-weld offset. If at any time the post tack-weld offset readings exceed specification allowables, the discrepant tack weld must either be rewelded or broken and retacked. The Quality Assurance representative records each incidence in which a tack weld was rewelded or broken and retacked. Upon satisfactory completion of all tack welds, the welding machine parameters are changed by the weld operator to conform to the requirements listed in the appropriate weld schedule for depositing the tack weld cover pass. The Quality Assurance representative then assures that the welding parameters listed in the applicable 971-D weld schedule conform to the weld parameters programmed on each welding machine. Before welding the cover tack-weld pass, a tack weld is deposited

Figure 5-1. Weld Offset and Gap Recording Prior to Tack Welding

7006-86-1454H

on a bead-on plate and compared to the bead-on plate standard established after acceptance of the applicable weld schedule. After visual comparison and acceptance of the newly deposited bead-on plate representing the tack-weld cover pass, the Quality Assurance representative provides an "OK" to weld. Upon completion of the tack-weld cover pass, the entire length of the cover pass is abrasively cleaned (on the outboard surface only) using a clean, stainless steel wire brush. All residue is then removed by vacuuming.

5.3 PENETRATION WELD PASS

The Quality Assurance representative must verify that the penetration-weld pass parameters listed in the applicable primary weld schedule are properly programmed on each welding machine. A penetration weld pass is deposited on a bead-on plate and compared to the bead-on plate standard. After visual comparison and acceptance of the deposited bead-on plate weld, the Quality Assurance representative gives the "OK" to weld. The Quality representative verifies that the Sanborn brush recorder is operable and also records on the Weld Data Sheet the weld start and stop locations of each welding power supply unit and the date and time each penetration weld pass was started and completed.

After completing the penetration weld pass, the responsible Manufacturing personnel survey the deposited weld bead to ensure adequate weld bead tie-ins and ensure that sufficient penetration has been achieved. If discrepant areas are detected and the primary weld schedule is certified with an appropriate supplemental weld pass procedure and related weld parameters, Manufacturing can reweld the discrepant areas. Quality Assurance personnel record the defective areas and the weld start and stop locations of each supplemental weld pass.

Manufacturing has the option at this time to either proceed with the cover weld pass or request an "information only" radiographic inspection of the completed penetration weld pass. Manufacturing generally requests the "information only" radiographs after the penetration weld pass on all circumferential welds in order to correct significant internal defects at the earliest point in time possible. Upon completion of the radiographic inspection, the responsible Quality Assurance and Manufacturing personnel review only the film views found to contain discrepancies as detected by the X-ray film interpreter. If discrepancies beyond the acceptable limits are found, Manufacturing has the option of performing a supplemental weld operation as long as (1) a supplemental weld operation was not previously employed in the same defect area, and (2) the supplemental weld operations and procedures were performed and listed when certifying the primary weld schedule for that specific sequence.

Prior to any mechanical grinding (grooving) operations for removal of discrepant zones in the weldment, a request for performing a supplemental weld operation (Figure 5-2) must be obtained and approved by S-II Manufacturing, Engineering, and Quality Assurance. The request for supplemental weld sequences identifies the end-item vehicle or major assembly number, location and type of weld, and location of each defective zone in which a supplemental weld operation will be performed. The Quality Assurance representative performs surveillance over all supplemental weld operations to ensure (1) that the areas identified on the supplemental weld request form are correctly identified and located on the weld; (2) that the Sanborn recorder is operable; (3) that the procedures and weld parameters listed in the primary weld schedule are followed; (4) that radiographic inspection is performed after each weld pass; and (5) that a weld pass is not deposited over an area in which an internal defect is located. Upon completion and acceptance of all areas in which the supplemental weld operations were performed, the Quality Assurance representative files a copy of the supplemental weld operation in the appropriate FAIR document and another copy in the Weld Quality Data Book.

5.4 COVER WELD PASS

The Quality Assurance representative must verify that the cover weld pass parameters listed in the applicable primary weld schedule are properly programmed on each welding machine. A cover weld pass is deposited on a bead-on plate and compared to the bead-on plate standard. After visual comparison and acceptance of the deposited bead-on plate weld, the Quality Assurance representative gives the "OK" to weld. The Quality representative verifies that the Sanborn brush recorder is operable and also records on the Weld Data Sheet the weld start and stop locations of each welding power supply unit and the date and time each cover weld pass was started and completed.

The Quality Assurance representative performs a complete visual inspection on the inboard and outboard surfaces of each weld (where possible) to verify conformance to the requirements defined in Process Specification MA0107-016.

Manufacturing personnel then mill both the face and root side of the weld using a Zephyr weld shaver until the bead is within $^{+0.005}_{-0.000}$ inches of being flush to the surfaces of the parent metal. After the milling operation is completed, the weld surfaces are polished to a surface finish of 125 RHR (or less) using Bear-Tex wheel chucked in an air drive motor.

IN-PROCESS REWORK REQUEST

MACHINE FUSION WELDING

Part Number	Unit No.	Serial No.	Dept.

SUPPLEMENTAL WELD OPERATION - METHOD NO. 1
(Undercut, Lack-Of-Fill, Suck-Back, Incomplete Penetration and Off-Center Weld Nugget Defects)

FAIR Book Sequence No. ________ 971-D Weld Sch. No. ________

Item No.	Type of Defect	Defect Location From	Defect Location To	Weld Pass Start	Weld Pass Stop

	Discrepancy Verif.	Date		Disposition Verif.	Date
M&P LAB.			INSP.		
INSP.			PROD.		
PROD.					

NOTE: Any change of weld wire or equipment from reference sequence must be recorded. No rework planning required for Method No. 1. - Ref. Specification MA0107-016.

SUPPLEMENTAL WELD OPERATION - METHOD NO. 2
(Oxides and Porosity Defects)

FAIR Book Sequence No. ________ 971-D Weld Sch. No. ________

Item No.	Type of Defect	Defect Location From	Defect Location To	Size

DISPOSITION (Rework Instructions to Planner)

	Discrepancy Verif.	Date	Planning Action	Date
M&P LAB.				
INSP.				
PROD.				

NOTE: Any change of weld wire or equipment from referenced sequence must be recorded. Rework planning required for Method No. 2. - Ref. Specification MA0107-016.

Temp. Form 0121-S Exp 6-11-69

M 000019

Figure 5-2. Supplemental Weld-Pass Authorization

Postweld offset or mismatch measurements of the weld joint are taken by Quality Assurance personnel using only instruments and equipment approved by Qualitv Assurance and the readings recorded in the applicable FAIR document. Any weld mismatch or offset measurements that exceed the allowables of the applicable process specification are squawked and submitted to the Material Review Board for disposition. A copy of the resulting Material Review Disposition Form 23-H-1 (MRD) is placed in the applicable FAIR document and a copy is retained in the Weld Quality Data Book.

Verification for final acceptance of each weld is achieved by appropriate radiographic (X-ray) and fluorescent-penetrant inspection operations.

6.0 REPAIR WELD CERTIFICATIONS

A welding repair schedule is a separate detailed procedure which is documented in the same manner as an NR SD primary weld schedule (Form 971-D) and provides complete details on the type of repair to be made on each applicable Saturn S-II weldment. This section defines the requirements applicable to all preweld preparation, welding parameters, and all preweld and postweld operations affecting the quality or strength of repaired welds. The repair weld schedules cannot be used for repair of production parts without the prior authorization of the Material Review Board.

Quality Assurance personnel verify that all requirements in the repair weld schedule are followed and that repair welds are not made without prior approval of the Material Review Board.

6.1 GENERAL REQUIREMENTS

Quality Assurance personnel must verify that operating personnel comply with all of the certification requirements listed in the applicable repair weld schedule and process specifications when the Material Review Board directs repair of a specific weld zone.

Before weld repair operations are initiated by Manufacturing, a technical review of the primary weld is conducted by Quality Assurance personnel to assure compliance with an existing weld repair schedule or to develop quality criteria for a new weld repair schedule. This review generally includes evaluations of the material thicknesses involved, type of weld joint discrepancies, existing weld joint configuration or condition, weld crossover considerations, effect of tee joints, etc. Upon completion of the review, Quality Assurance publishes a memo to Manufacturing defining the limitations associated with groove-out configurations and the numbers and types of test specimens requested or required for certification to verify the feasibility of a particular weld joint repair schedule. Quality Assurance technical personnel witness and verify that the weldments fabricated to simulate the repair area(s) were accomplished using identical weld parameters and procedures as those defined in the applicable primary weld schedules.

6.2 GROOVE-OUT CONFIGURATION

If the Quality Assurance review of the primary weld disclosed that the weld to be repaired was made in the horizontal position, then all weld groove-out zones are located in the upper half of the weld bead. The rationale is that this is the area of a weld made in the horizontal position in which approximately 90 percent of all porosity and/or oxide discontinuities are detected during nondestructive testing (i.e., X-ray or fluorescent-penetrant inspections). This condition is generally due to the natural tendency of these types of defects to float and rise to the top of the puddle when the weld metal is in the molten state.

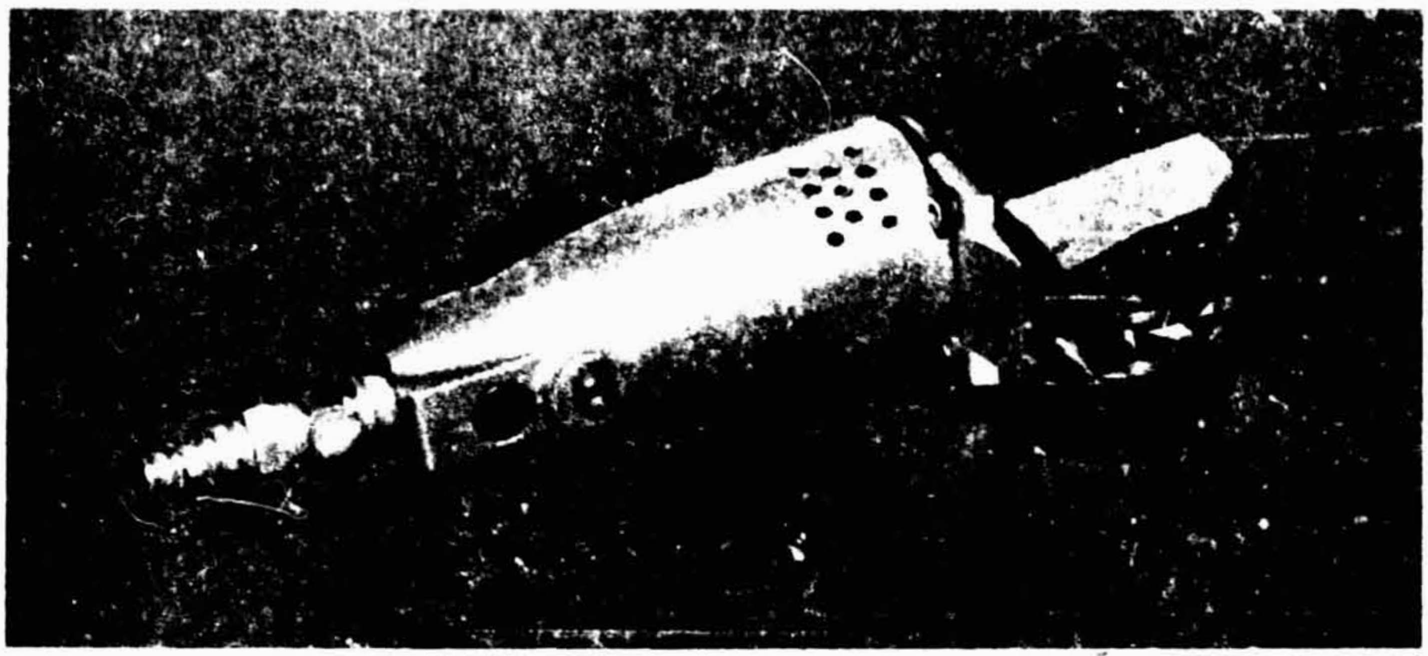
During all repair operations in which defects are mechanically removed by grooving, a maximum groove-depth limit is established. Generally, the groove must not exceed a depth equal to 60 percent of the parent metal thickness of the weld and the groove width must not exceed that of the existing weld bead. All precautionary measures are imposed to prevent the finished repair weld from exceeding the width of the original weld bead, thereby preventing a detrimental effect (e.g., strength reduction) on the adjacent parent metal structure.

Manufacturing determines the actual groove configuration consisting of groove depth, width, length, and angle of weld taper-in and taper-out zones. When completed, Quality Assurance personnel verify that the groove configurations conform to the dimensions established by Manufacturing.

The types of grooving tools utilized by Manufacturing (Figure 6-1) are authorized in the applicable repair weld schedule (Form 971-D). Quality Assurance personnel record the type of tool employed for each operation. The tool normally used by Manufacturing in preparing a groove configuration is depicted in Figure 6-2. It is not mandatory (because of accessibility problems frequently encountered) for Manufacturing to use the identical grooving tool on production parts as those identified in the applicable repair weld schedule. However, adherence to this practice is highly recommended and is accomplished by Manufacturing wherever possible.

6.3 CLEANING

The final groove configuration is abrasively cleaned by brushing (in one direction only) using a clean, stainless steel wire brush. Generally, an area at least 12 inches long and 2 inches wide (6 inches fore and aft of the defect zone and 1 inch above and below the groove-out) is thoroughly cleaned in this manner. The area is further cleaned by wiping the affected surface with clean cheesecloth dampened (not saturated) with acetone or MEK.



7006-86-1354C

Figure 6-1. Tool Used for Weld-Groove Configurations

7006-86-1354H

Figure 6-2. Technician Using Tool to Prepare Weld-Groove Configuration

6.4 REPAIR WELD CERTIFICATION PROCEDURE

Before welding the defect on the actual hardware, a repair weld certification procedure is established. Before welding the specimens that will be used in evaluations to certify the repair weld schedule, Manufacturing establishes the weld parameters intended for use. This is done by weld filling groove-out practice areas exhibiting the same configuration as contained in the certification test specimens. The Quality Assurance representative verifies that welding parameters established on the repair weld schedule are properly programmed on the welding unit to be employed for preparing the repair weld test panels for certification. The responsible certified welding operator then deposits the first weld pass in the simulated defect zone, starting and stopping the weld pass as close to the taper-in and taper-out portion of the groove as possible. The exception is that in areas near weld intersections, starting and stopping of a weld sequence or pass is not permitted within an area measuring 2 inches in length from either side of the weld-bead crossover point. The excess weld bead metal is mechanically removed using a Zephyr weld-bead shaver until the bead is approximately flush with the parent metal surface. The weld test panels containing the first weld pass are then submitted to Quality Assurance for radiographic (X-ray) inspection. After acceptance of the radiographs by responsible Quality Assurance personnel, the test specimens are returned to Manufacturing for preweld cleaning by wire brushing and solvent wiping (as previously described) and deposition of the second weld pass. This operation begins after Quality Assurance verifies that the welding parameters listed on the intended or new repair weld schedule are properly programmed on the same welding equipment previously employed for depositing the first weld pass.

These processing steps (cleaning, welding, inspecting) are repeated until the groove-out in the test specimens are filled with weld metal. The excess weld bead metal is then milled flush to within $^{+0.005}_{-0.000}$ inch of the parent metal surface using a Zephyr weld-bead shaver. The milled areas are then abraided using a Bear-Tex wheel or pad to provide a surface finish of 125 RHR or less. The specimens are next submitted to Quality Assurance technical personnel for acceptance in accordance with the visual, radiographic, and fluorescent-penetrant inspection requirements listed in Specification MA0107-016, Revision H, and described in Section 3.0.

After acceptance of the repair by nondestructive testing, the test panels containing the certification weldments are machined into mechanical properties tensile and bend-bar test specimens. This procedure is identical to that described in Section 3.0 for primary machine weld certification.

6.5 MECHANICAL TESTS

In Section 3.0, the type and numbers of mechanical tensile and bend-bar specimens required for certification of the propellant tank circumferential and vertical cylinder splice welds, aft LO_2 bulkhead, forward LH_2 bulkhead, forward common bulkhead, and the aft common bulkhead meridian welds are defined. Following is a summary of the types of certification requirements that could be imposed on Manufacturing (as authorized by the Material Review Board action) during repairs of such welds:

1. A repenetration machine weld pass, followed by a machine weld cover pass.

2. Mechanically grooving a weld bead to a depth measuring not more than 60 percent of the total parent metal thickness, followed by filling passes using manual welding techniques. The manual weld filling operation is followed by a machine weld cover pass or passes.

3. Machine weld filling back-to-back weld metal that is grooved to a depth measuring not more than 60 percent of total parent metal thickness. Each grooved zone is filled by machine welding before regrooving and rewelding the opposite side of the previously grooved area.

For noncrossover and nonweld intersection areas, test specimens consisting of five tensile and four bend bars are prepared and tested. The weld beads are positioned in location that is transverse to the length of the test specimen. The four bend-bar specimens are tested with the repair side of the weld maintained in tension. The tests are conducted as described in Section 3.0.

For weld crossover and intersection areas (tees), mechanical test specimens consisting of five tensile and four bend bars are cut from the certification test panels and machined. The weld beads on three of the five tensile bars are positioned in a direction transverse to the length of the test specimen. The weld beads on the other two tensile bars are placed longitudinally to the length of the test specimen. Two of the four bend-bar specimens are tested with the face side of the repair weld maintained in tension; the other two are tested with the root side maintained in tension. All specimens are then tested using the procedures defined in Section 3.0. After acceptance of all test data, the responsible Quality Assurance technical representative assigns a repair weld schedule number to the applicable 971-D form. The repair weld schedule is then signed by Quality Assurance and submitted to the responsible Engineering and Manufacturing representatives for approval.

The original copy of the repair weld schedule and all related test data are maintained by Quality Assurance. Copies of the repair weld schedule are then submitted to Manufacturing, Engineering, and responsible Quality Assurance personnel. The responsible technical Quality Assurance representative includes the repair weld schedule number and description to the current weld schedule roster which is updated monthly by Quality Assurance.

7.0 WELD QUALITY DATA BOOK

The Quality Assurance organization maintains a technical, in-process record on Weld Quality Data Sheets of all primary fusion welds made on Saturn S-II stages. The individual data sheets comprise a Weld Quality Data Book for each S-II stage, which is used for technical reference purposes during quality-oriented activities involving Material Review actions, quality analysis, stage flightworthiness evaluations, etc.

Quality Assurance technical personnel monitor or direct all pertinent activities performed during a specific primary fusion weld operation and record all data necessary to verify acceptance of that weld. Quality Assurance personnel assigned to accomplish technical surveillance of a weld operation are responsible for the accurate recording of all welding data and the verification of such data utilized in subsequent analyses.

7.1 GENERAL REQUIREMENTS

The documentation of primary welding and repair operations includes descriptions of all significant activities that have a direct or potential detrimental effect on the quality and reliability of the vehicle. The welding operations considered significant on the S-II stage include preweld verification testing, preliminary welding operations (including environmental controls related to preweld cleaning), fitup, weld tacking, weld penetration, cover weld passes, supplementary welding, weld repair operations, and final acceptance of the primary weld.

The propellant tanks (LO_2 and LH_2) comprising any S-II stage are subjected to a pneumostatic pressure test after the completion and quality acceptance of all the primary structural welds. After this major milestone test, the weld areas are subjected to visual, radiographic, and fluorescent penetrant inspections. Any defects detected in these inspections must be evaluated, repaired if necessary and the results documented. The significant detailed sequences associated with the operations for each of these activities must be recorded.

7.2 PREWELD VERIFICATION

The Quality Assurance technical representative directs welding of the test specimens as described in Section 4 of this document. The completed weld is inspected visually, followed by radiographic and fluorescent penetrant inspections. The results of the visual inspection are noted by the technical representative for inclusion in the historical summary of data related to that particular weld. The copies of the radiographic and penetrant inspection results are retained as part of the weld data package and become part of the Weld Quality Data Book.

7.3 PRIMARY WELDING

All significant tasks associated with each primary welding operation must be recorded. Other activities that could affect the quality of the weld are recorded if judged sufficiently important. Out-of-scope activities such as variances of machine parameters in excess of allowable specification tolerances during actual welding sequences, rewarding without authorization, contaminating the weld joint, or variance from the 971-D weld schedule are typical of important activities that must be recorded for subsequent evaluation. The specific in-process details (i.e., required parameters and actual values obtained) that must be recorded in the weld station on appropriate forms during welding operations are as follows:

1. General Information — The vehicle number, specific weld involved, weld power supply identification numbers, Weld Schedule Number, FAIR book unit number, serial number and assembly number, building number, floor, and station.

2. Environmental Control — The particle count temperature, relative humidity, purity of shielding and purge gases, and the general condition of area cleanliness (i.e., no visible dirt, dust, etc.)

3. Preweld Joint Cleaning — Start dates and completion times of significant tasks are documented, along with any pertinent observations related to incidents occurring during the cleaning cycle that are judged to be valid data.

4. Tack Welding (Intermittent and Continuous)—The dates and tack-weld start and completion times, the position where the weld is started and completed (as measured in inches from Point 0), weld power supply identification numbers, the manufacturer's heat number and lot number of the weld filler wire, and the offset dimensions of the weld joint after tacking. The offset dimensions are recorded by Quality Assurance and copies are retained as part of the FAIR book and Weld Quality Data Book.

5. Penetration Weld Pass — The dates and penetration weld start and completion times, and the position where each weld machine was started and stopped (measured in inches from Point 0). All data associated with any significant incident occurring during the welding cycle, such as variance from the certified Weld Schedule, machine parameters, and unscheduled weld stops and starts, are recorded. After the penetration pass is radiographically inspected, copies of the X-ray reports are retained in the Weld Quality Data Book for reference purposes.

6. Supplementary Welding Sequences—The types and description (size and location) of defects encountered, the radiographic (X-ray) report control number, the number of X-ray views withheld, weld joint configuration prior to rework and the configuration resulting from the rework, the welding parameters used to complete the weld operation, the defective zones repaired (as measured from Point 0), and the total inches of weld repaired.

7. Cover Weld Pass—The dates, weld start and completion times, the start and stop position of each weld unit (as measured in inches from Point 0), the power supply identification numbers, and the description and location of any supplementary weld passes. The procedures for documenting supplementary weld passes are identical to those employed for the penetration weld pass described in Item 5. If more than one weld cover pass is required, the operation is documented in the same manner as the first weld cover pass.

8. Final Inspection of the Weld — The radiographic (X-ray) report control number, the number of X-ray views withheld, the Material Review Disposition (MRD) number, the number of views repaired, the total inches of weld repaired and defect descriptions (location and size). The same data are recorded for fluorescent penetrant inspections. Copies of the radiographic and penetrant inspection results are retained for inclusion in the Weld Quality Data Book. The requirements for documentation of weld repairs are detailed in Section 6 of this volume.

7.4 WELD REPAIR OPERATIONS

The activities associated with weld repairs are directed by the Quality Assurance technical representative. The responsibilities include documenting data pertinent to the following operations:

1. General Information—The specific weld involved, the vehicle number, the Material Review Disposition number and page, the

squawk number and date, the weld defect location (inboard or outboard), the method of detection (i. e., visual, radiographic or fluorescent penetrant), and the defect location (size and type) as measured in inches from Point 0.

2. Procedure for Repairing Defect—The exact location of the defect as determined by radiographic interpretation (including the use of triangulation techniques), the location of the groove-out over the defect, the final groove configuration (length, width, depth), and the Form 971-D Repair Weld Schedule number used for repairing the weld. The typical weld repair requires more than one weld pass; therefore, each pass is documented and the results of the radiographic inspection recorded for each pass as previously described.

Special Notes

Layer weld passes utilizing a side-by-side technique are counted as two weld passes. Any deviations from the certified weld repair parameters will be recorded by Quality Assurance. All copies of the applicable Material Review Disposition are included as an integral part of the Weld Quality Data Book.

After completion and acceptance of the weld repair, the Quality Assurance technical representative reviews the recorded information, including copies of the Material Review Disposition, radiographic and fluorescent penetrant inspection results, and all notes pertinent to the operation. After the review, the technical representative includes the weld repair history in a Quality Memo summarizing the work effort for the specific weld involved. A typical Quality Memo is shown in Figure 7-1.

Pneumatic Pressure Testing

The final acceptance testing of primary fusion welds contained in S-II stages involves pressurization of the LH_2 and LO_2 tank structures, followed by radiographic and fluorescent penetrant inspection of the weld zones. Quality Assurance technical representatives and Engineering design personnel review the results of such major tests. Defects resulting from these tests are dispositioned by the Material Review Board. If repairs are required, the Quality Assurance representative follows the same procedures used for accomplishing standard repair activities. After completion of the repair activities and recording of data, the Quality Assurance technical representative prepares a report summarizing the repair activities. The report includes descriptions of the methods used for locating defects, the locations of the defects, and the repair disposition associated with the defects. The report also is included as part of the Weld Quality Data Book.

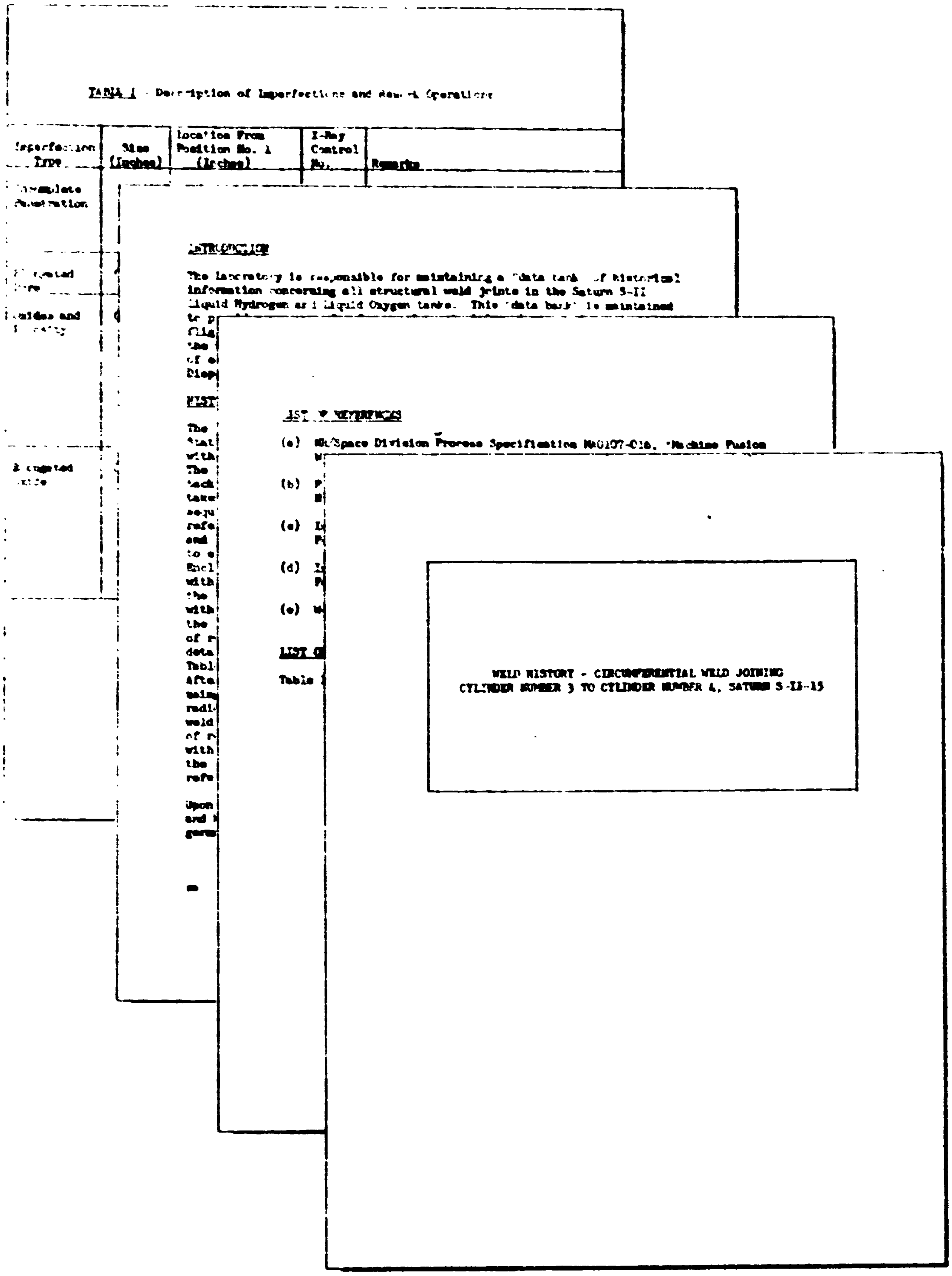


Figure 7-1. Typical Quality Memo

7.5 WELD QUALITY DATA BOOK

The Quality Assurance technical representative is reponsible for collecting all the required documentation for a specific weld and preparing it for inclusion in the Weld Quality Data Book. The following items are typical of the documentation contained in the Weld Quality Data Book:

1. Lab Memo summarizing the history of the weld
2. Weld quality data sheets
3. Weld offset measurements
4. Weld repair history sheet
5. Radiographic and fluorescent penetrant inspection records
6. Material Review Dispositions
7. Test reports - welding gas analysis, particle counts, etc.
8. Mechanical properties test results, if applicable.
9. Drawings of specific areas, if applicable

APPENDIX A

TYPICAL ACCEPTANCE TEST SPECIFICATION

ACCEPTANCE TEST SPECIFICATION

Machine-Type Automatic GTA, Fusion Welding Equipment

Contents

Space Division
North American Rockwell

1. SCOPE:

This specification covers operational uniformity requirements for the equipment which shall be performed in conjunction with procurement specification requirements.

2. APPLICABLE DOCUMENTS:

2.1 S&ID Policies and Procedures F-425, dated 10 December 1962.

2.2 Procurement Specification SB-0-63-48, Revision A

3. REQUIREMENTS:

	CHECK	RESULTS *Not Applicable, Unsatisfactory, or Satisfactory. Comments
3.1	Power Supply – DC:	
3.1.1	A power "on-off" switch.	______
3.1.2	Constant current-constant potential 600 amp, 100 percent duty cycle.	______
3.1.3	DC power supply in a separate sheet metal cabinet.	______
3.1.4	Silicone rectifier control.	______
3.1.4.1	Primary power input of 460 volts, 3 phase, 60 cycles.	______
3.1.5	Maximum open circuit voltage of 85.	______
3.1.6	When used as a constant current mode, current to be stepless from 6 to 600 amps.	______

Space Division
North American Rockwell

3.1.7	When used as a constant potential mode, voltage to be stepless from 0 to 60 volts.	________
3.1.8	Current and voltage will be by direct reading dials.	________
3.1.9	Weld current output stabilized from minimum to maximum in 10 cycles or less.	________
3.1.9.1	Overshoot current stabilization stabilized in 10 cycles or less.	________
3.1.10	System able to maintain preset dial settings within $\pm$ one percent or 2 amps, whichever is greater, within the following variables:	________
3.1.10.1	Primary line voltage change of $\pm$ ten percent.	________
3.1.10.2	Length of control and power cable.	________
3.1.10.3	Changes in welding arc voltage.	________
3.1.10.4	Weld length of 50 feet minimum in all positions.	________
3.1.11	Up and down slope provided.	________
3.1.11.1	Initial slope current and timing initiated on arc establishment and is independent on voltage setting.	________
3.1.11.2	Initial current value continuously adjustable from a minimum of six to a maximum of 600 amperes.	________

3.1.11.3	Initial current slope dial is direct reading.	____________
3.1.11.4	Initial current slope timer controlled by a single range dial from 0 to a minimum of 100 seconds.	____________
3.1.11.5	Slope control automatically initiated when the sequence stopbutton is depressed.	____________
3.1.11.6	Final slope current adjustable from 600 to a minimum of 6 amperes.	____________
3.1.11.7	Direct reading dial to set final slope level.	____________
3.1.11.8	Single dial, 0- to 100-second final slope timer.	____________
3.1.11.9	Initial and final slope is smooth and automatic.	____________
3.1.11.10	0- to 100-second current stop delay.	____________
3.1.11.11	Current stop delay automatically initiated when the sequence stopbutton is depressed.	____________
3.1.12	Single, secondary polarity reversing switch.	____________
3.1.13	During a 30-minute run the machine's output does not vary from a preselected setting by more than one percent throughout the machine's range.	____________
3.1.14	Flush-mounted primary power switch in machine's front panel to disconnect all primary power.	____________

3.1.15	Remote control station, reference, Paragraph 3.6.2.	______
3.1.15.1	Face-mounted control dials, switches, and meters on the front side of power supply.	______
3.1.15.2	Direct reading voltage and current dials on the remote control panel.	______
3.1.16	Output and control leads have quick disconnect fittings locally grouped.	______
3.1.16.1	Quick disconnect fittings are not interchangeable except for electrode and ground leads. These exceptions are color coded.	______
3.1.16.2	No exposed potential on quick disconnects when disconnected.	______
3.1.17	25-foot primary cable.	______
3.1.17.1	Crouse Hinds Arctite (Type 2) male connector. Cat. No. AP10467.	______
3.1.17.2	Single input cable to provide power to power supply, controls and accessories.	______
3.1.18	Power reduced from 460 volts to 115 volts with a minimum of 3 kva for controls and accessories.	______
3.1.19	Heavy duty, mill-type primary contactors.	______
3.1.20	Thermal overload and protective devices provide safe machine shutdown should overheating occur.	______

3.1.21	Weld current adjustment does not cause moving of major cores or major section of transformers.	______
3.1.22	Line overloads not to be tripped when primary in-rush current is applied across welding transformer.	______
3.2	<u>Skate System (Automatic Welding Head)</u>	
3.2.1	Automatic GTA constant arc voltage welding head interconnected with control panel.	______
3.2.2	Automatic weld head capable of welding with the following GTA Processes.	______
3.2.2.1	DC straight polarity.	______
3.2.2.2	DC reverse polarity.	______
3.2.3	Arc voltage automatically controlled within $\pm$ 0.1 volt, regardless of variables specified in Section 3.9.	______
3.2.4	Arc voltage head controlled by remote arc voltage dial.	______
3.2.4.1	Remote arc voltage dial graduated in 0.1-volt increments.	______
3.2.4.2	Remote arc voltage dial adjustable from 0 to 40 volts.	______
3.2.4.3	Remote arc voltage control within 0.1 volt.	______
3.2.5	Minimum of two inches arc voltage travel for miniature head.	______

3.2.6	Arc voltage controlled head operates in all positions.	______
3.2.7	Limit switches to limit maximum head travel.	______
3.2.8	Welding head to provide a backlash-free linear motion regardless of head position.	______
3.2.9	Motorized cross seam slides with minimum of two inches of adjustment.	______
3.2.10	Weld head has tilting provisions to obtain a cross seam angle of $\pm$ ten degrees.	______
3.2.10.1	Weld head cross seam angle calibrated in two-degree increments.	______
3.2.10.2	Cross seam slides are quick-change type.	______
3.2.11	The weld head has tilting provisions of at least $\pm$ 30 degrees along the seam, calibrated in 2 degree increments. Quick change ability without disassembly.	______
3.2.12	Mechanical weld head provides support for torch holder, torch, and wire feed guide.	______
3.2.13	Voltage rate of response capable of 0 to 80 ipm.	______
3.2.14	Automatic locking solenoid to lock head after arc is extinguished.	______

3.3	Torch:	
3.3.1	Water cooled GTA torch - type SW6, rated at 600 amperes dc.	______
3.3.1.1	All standard size collets, cups, contact tubes, adapters, and other hardware to complete torch installation and interconnection provided.	______
3.3.2	Torch to accept standard tungsten diameters from 0.020 to 0.250 inch.	______
3.3.2.1	Brackets to allow changing of tungsten without removing torch or torch nozzle.	______
3.3.2.2	Torch movable forward and backward.	______
3.3.2.3	Collets for all tungsten diameters included.	______
3.3.3	Torch holder complete with one set of shielding gas cups and accessories, water hose, water-cooled conductor, cable and shielding gas inlet hose.	______
3.3.4	50-foot hose assembly with quick disconnect fitting.	______
3.3.5	Check valve installed in the torch to prevent atmosphere aspiration into the inert gas supply.	______
3.4	TIG wire feed system:	
3.4.1	Capable of feeding soft wire in diameters of 0.045 to 0.062 inch.	______
3.4.2	Wire speed steplessly adjustable from 1 to 100 ipm.	______

3.4.2.1	Wire feed control has a direct reading dial calibrated in inches per minute.	______
3.4.3	Complete set of grooved wire feed rollers, wire feed nozzles, and flexible conduit for wire diameters of 0.045 to 0.062 inch.	______
3.4.3.1	Feed rollers mounted so as to preclude loosening during operations.	______
3.4.4	Wire feed positioner of compact assembly designed with motorized vertical and horizontal guide tip motion.	______
3.4.4.1	Horizontal adjustment of the wire guide tip or the pendant station will be 1-1/4 inch from the electrode.	______
3.4.4.2	Vertical adjustment of the wire guide tip is between 15 and 35 degrees from the horizontal.	______
3.4.4.3	Wire positioner complete with mechanism to clamp or fasten in the operating position of the weld torch.	______
3.4.4.4	Weld torch easily removed and installed with wire feeder in position.	______
3.4.4.5	Provide wire guide tips and wire casings of 0.045 and 0.065 inch in diameter.	______
3.4.4.6	Wire feed mechanism and filler wire spool cover electrically insulated.	______

3.4.4.7	Wire feed mechanism and filler wire spool covered to prevent contamination.	________
3.4.4.8	Wire feed mechanism easily removed.	________
3.5	<u>Weld carriage and travel drive motor systems:</u>	
3.5.1	Weld travel carriage and drive motor system complete with dc gear motor nd tachometer.	________
3.5.2	Dc drive motor mounted on skate carriage, individually suspended and supported on skate with quick change replacement provisions.	________
3.5.3	Travel speed preset by direct reading dial steplessly adjustable from 1 to 100 ipm.	________
3.5.4	Carriage drive motor provided with method of disengaging drive system.	________
3.5.5	Skate carriage completely assembled with all brackets and assemblies, ready for a production weld.	________
3.6	<u>Control System:</u>	
3.6.1	Main Station:	
3.6.1.1	General:	
3.6.1.1.1	GTA welding functions housed in sheet metal cabinet.	________

3.6.1.1.1.1	Each control system (wire feed, carriage travel, arcweld head and sequence) mounted in module type vertical pullout drawers and interconnected by quick disconnect plugs.	______
3.6.1.1.1.2	All modules interchangeable among like machines.	______
3.6.1.1.1.3	RC-type timers on timing functions.	______
3.6.1.1.1.4	Controls provide a complete automatic program welding sequence.	______
3.6.1.2	DC Current Control System:	
3.6.1.2.1	Stepless adjustable direct reading system from a 6-amp minimum to 600 amperes.	______
3.6.1.2.2	Dc ammeter 0 to 600 amps reference meter, face mounted on main station and accurate to within 2 percent of meter full-scale deflection.	______
3.6.1.2.3	DC current overload switch on face of main panel.	______
3.6.1.2.4	Stepless adjustable direct reading dial to control initial slope current.	______
3.6.1.2.5	Initial current slope timer 0 to 100 seconds minimum.	______
3.6.1.2.6	Stepless adjustable direct reading dial to control final slope current from 600 amps to at least 6 amperes.	______
3.6.1.2.7	Final slope current timer adjustable from 0 to a minimum of 100 seconds.	______

3.6.1.2.8	Current stop delay timer adjustable from 0 to at least 100 seconds.	______
3.6.1.3	DC Voltage Control System:	
3.6.1.3.1	Stepless adjustable direct reading dial from 0 to 40 volts, acc ate to within 0.1 volt.	______
3.6.1.3.2	Referenc , DC voltage meter, face mounted on the main station, accurate to within 2 percent of the actual arc voltage value.	______
3.6.1.3.3	Arc voltage initial and final slope controls. Slope magnitude for initial and final voltage adjustable from 0 to 40 volts. Slope rate for initial and final adjustable from 0.1 to 100 seconds.	______
3.6.1.4	Carriage Travel Control System:	
3.6.1.4.1	Maintain preset weld travel speeds within one percent from 1 to 100 ipm regardless of loading in excess of 25 feet. A reversing switch with equal speed control.	______
3.6.1.4.2	Start delay timer adjustable from 0 to at least 100 seconds. Timing to start immediately after arc is established.	______
3.6.1.4.3	Travel stop delay timer adjustable from 0 to a minimum of 100 seconds and will start when sequence stop button is depressed.	______

3.6.1.5 Wire Feed Control System:

3.6.1.5.1 Accurate to within ± one percent from 1 to 100 ipm. ______

3.6.1.5.2 Direct reading dial steplessly adjustable from 0 to 100 ipm, with reversing switch. ______

3.6.1.5.3 Initial and final slope control of wire feed presetable from 0 to 100 ipm. ______

3.6.1.5.4 Initial and final slope control timer presetable from 0 to 100 seconds. ______

3.6.1.5.5 Start delay timer adjustable from 0 to 100 seconds. Timing to start immediately after arc establishment. ______

3.6.1.5.6 Stop delay timer adjustable from 0 to 100 seconds. Timing to start when sequence stop button is depressed at remote control station. ______

3.6.1.5.6.1 Wire retract control to approximately 45 cycles after wire feed stops. ______

3.6.1.5.6.2 The retract time will be fixed and the rate adjustable from 0 to 50 ipm. ______

3.6.1.6 Impulse Arc Starting Device and Controls:

3.6.1.6.1 Capable of initiating a welding arc across a 1/8 inch gap at six amperes in argon or helium with a cold electrode, with cable length of 50 feet. ______

3.6.1.6.2	Unit mounted inside or on control cabinet.	______
3.6.1.7	Water System and Controls:	
3.6.1.7.1	Completely closed circuit water cooling system to allow continuous 600 amp operation without torch damage for one hour minimum. Pressure adjustment from 0 to 80 psi.	______
3.6.1.7.2	Visual flow-type indicator.	______
3.6.1.7.3	Safety water flow switch to prevent arc starting without water flow. If water flow fails during the welding operation, this unit will actuate the weld stopping sequence.	______
3.6.1.7.4	Silent operating bearing relief valves.	______
3.6.1.8	Gas System and Controls:	
3.6.1.8.1	Capable of controlling argon and/or helium during welding for torch and backup gas.	______ ______
3.6.1.8.2	Separate two-stage regulators and dual flow meters supplied for each type of gas for both weld torch and backup gas.	______ ______
3.6.1.8.3	Flow indicator range 1 to 190 cfh.	______
3.6.1.8.4	Gas control unit interconnected to supply either gas or composite of both gases mixed in prescribed quantities to welding torch.	______

3.6.1.8.5	Backup gas and torch gas controlled by a solenoid valve.	______
3.6.1.8.6	Purge switch in the main control station.	______
3.6.1.8.7	Flowmeters connected into the control package as an integral part of the control system.	______
3.6.1.8.8	Pregas and postgas flow timers adjustable from 0 to a minimum of 100 seconds.	______
3.6.1.8.9	Pregas timer to prevent arc initiation until after preflow timing is complete.	______
3.6.1.8.10	Post-flow timer initiated when the weld arc is extinguished.	______
3.6.2	Remote Control Pendant Stations:	
3.6.2.1	Dc steplessly adjustable direct reading dial from 0 to 40 volts.	______
3.6.2.2	Dc current direct reading dial steplessly adjustable from 6 to 600 amps.	______
3.6.2.3	Wire feed direct reading dial steplessly adjustable from 1 to 100 ipm.	______
3.6.2.4	Carriage travel forward and reverse switch and a direct reading dial steplessly adjustable from 1 to 100 ipm.	______
3.6.2.5	Carriage travel switch to select run or jog speed.	______
3.6.2.5.1	Separate jog speed potentiometer to set jog speed.	______

3.6.2.6	Wire feeder forward and reverse jog switch.	________
3.6.2.7	Weld head position switch to jog head toward and from work.	________
3.6.2.8	Switch to allow or lock out arc voltage control.	________
3.6.2.9	Manual-automatic selector switch. When in automatic, carriage speed controlled by weld sequence panel.	________
3.6.2.9.1	Automatic off manual switch and jog switch on carriage to set up wire feeder.	________
3.6.2.10	Weld-start pushbutton switch to start a sequence of operations culminating in a welding arc.	________
3.6.2.11	Sequence stop button to initiate a sequence of operations required to end a weld.	________
3.6.2.12	Cross seam adjustment (left-right) switch.	________
3.6.2.13	Emergency stop switch to stop all functions except post-flow gas.	________
3.6.2.14	Direct reading dials shall have digital readout where only the number concerned is visible.	________
3.6.2.15	Dials securely fastened to potentiometer shafts.	________
3.7	<u>Cables Hose Assemblies and Wiring</u>:	
3.7.1	All output and control leads such as electrode leads, etc., are quick-disconnect type.	________

3.7.2	Water and gas hoses have quick-disconnect fittings and cannot be misconnected.	________
3.7.3	The following cables and hose assemblies are provided:	
3.7.3.1	Extra flexible, lightweight grounding cable with quick-disconnect fittings, female fitting at the ground clamp and a male fitting at the machine end.	________
3.7.3.2	Fifty-foot ground cable.	________
3.7.4	Fifty-foot power cable (electrode) with quick disconnects.	________
3.7.5	Cables and hoses emanating from the skate terminate at the main control cabinet.	________
3.7.5.1	Fifty-foot cables from control station to remote control station.	________
3.7.6	External control cables shielded.	________
3.7.7	Cables not directly connected between remote control station and skate.	________
3.7.8	Electrical control cables protected by a plastic zipper tube casing.	________
3.7.9	Electrical interconnection cables for pendent control stations interchangeable with like machines.	________

3.7.10	Electrical interconnection cables for skate control interchangeable with like controls.	______
3.7.11	Minimum wire size of number 20 with numbered terminal strips.	______
3.8	<u>Equipment Carriage</u>:	
3.8.1	Adequate equipment carriage.	______
3.8.2	Spring-loaded tow bar.	______
3.8.3	Gas bottle (two) storage rack with safety chains and hooks.	______
3.8.4	Provision for cable storage.	______
3.8.5	Lift lugs on equipment to support overhead handling.	______
3.9	<u>Penetration Control</u>:	
3.9.1	Penetration control system.	______
3.9.2	Arc penetration sensor assembly.	______
3.9.3	Transducer oscillator and power supply.	______
3.9.4	Operator control station with interconnecting cable to the oscillator and to a dc power supply.	______
3.9.5	Penetration control produces uniform weld nuggets, including bead geometry.	______
3.9.6	Automatically adjusts the magnitude of welding current so that a constant welding electrode position sensor will maintain a constant predetermined weld penetration.	______

3.10 **Engineering and Maintenance Information Section:**

3.10.1 Meets requirements of Section Number 8 of Procurement Specification SB0-0-63-48, Revision A.

APPENDIX B

TYPICAL WELDING SCHEDULE

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Space Division
North American Rockwell

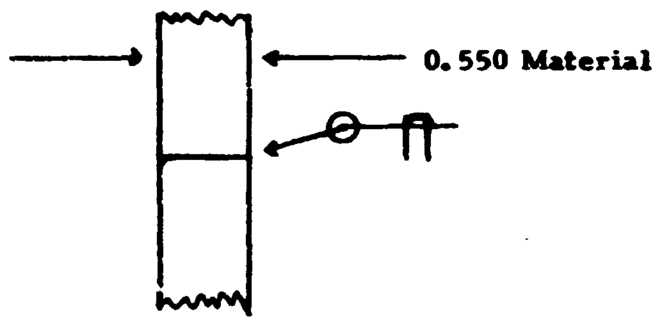
NORTH AMERICAN AVIATION, INC.
SPACE and INFORMATION SYSTEMS DIVISION

Approvals			FUSION WELDING PROCESS REQUIREMENT SCHEDULE	Schedule No. 00550	
Dept	Signature	Date		Date 5/16/69	
Mfg				Supersedes Schedule Date 2/28/69	
Q.C.				Rev Ltr B	Page 1 of 11
Eng					

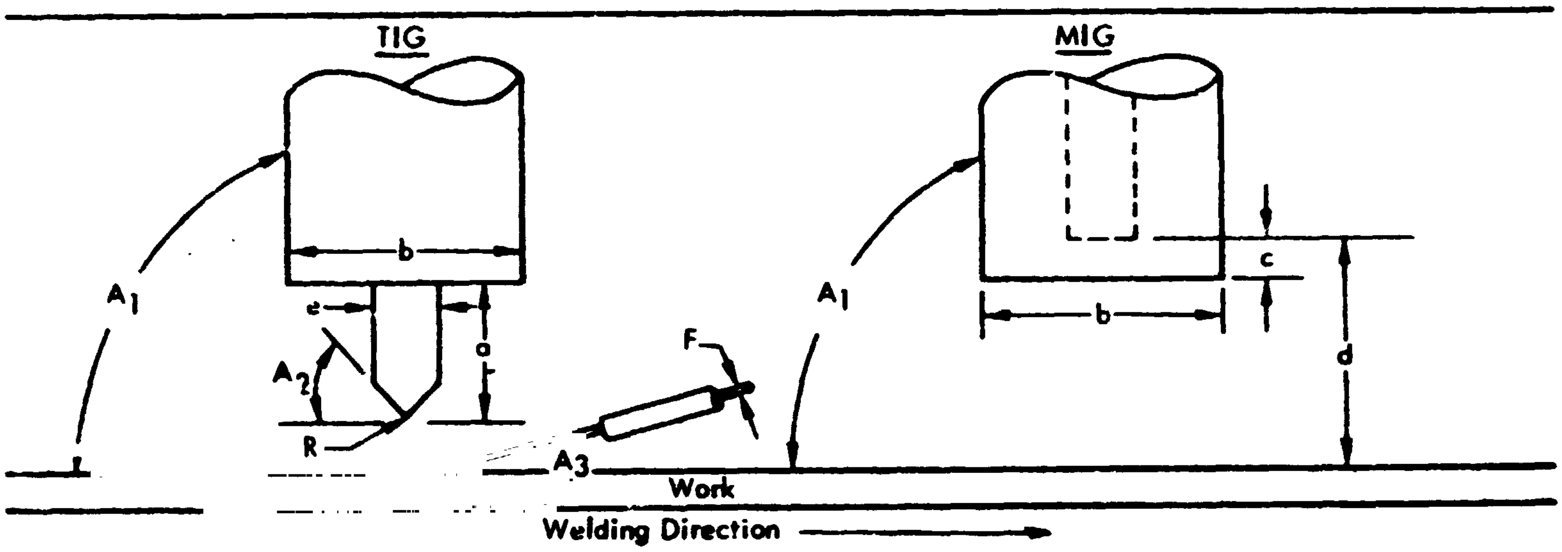
(Used in conjunction with Process Specification No. MA0107-016)

Assembly No.	V7-333002	**Materials:**		**Parameters:**	
Sciaky Tool No.	T-7201985	Base Metal	2014-T6	Potential	Pages 8 & 9
Sciaky ~~Process~~	T-7201987	Filler Alloy	4043	Current	Pages 8 & 9
Sciaky Process	T-7201988	Electrode	Tung. 2% Thor	Filler Rate	Pages 8 & 9
Process	TIG-D.C.S.P.	Shield Gas	Helium Reactor Grade	Welding Rate	Pages 8 & 9
				Shield Gas Rate	110 CFH

JOINT DESIGN



Primary Weld Schedule for Aft LO_2 to Common Bulkhead (Girth Weld)



A_1	Angle of Electrode Holder 90° ± 7° Lead	a	Electrode Stickout 1/2"
A_2	Angle of Taper of Electrode Page 7	b	Diameter of Cup 5/8"
A_3	Angle of Wire Feed 30°	c	Depth of Contact Tube Recess —
R	Radius of Electrode Tip —	d	Contact Tube to Work Distance —
F	Filler Alloy Diameter 1/16"	e	Electrode Diameter 5/32"

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Welding Procedure: (Cont)

Fusion Weld Process Requirement Schedule (Con't)

1. Position parts for preweld joint preparation in T-7200015 for cleaning.
2. All base material will be handled with lint-free gloves.
3. Gloves used for handling tools shall not be used for handling base materials.
4. Remove strippable vinyl coating from weld lands.
5. Acetone wipe weld lands approximately 3 inches on each side of weld joint.
6. Acetone will be applied only with damp cheesecloth. DO NOT SATURATE CLOTH.
7. Bear-Tex external and internal surface approximately 1 inch on each side of butt face (manual or rotary wheel optional). For Chem-Film only. Do not Bear-Tex abutting surfaces.
8. Wipe with acetone.
9. Draw file inside and outside of top cylinder, approximately 2-inches minimum, along weld joint to remove Chem-Film.
10. Draw file inside and outside of bottom cylinder, approximately 2-inches minimum, along weld joint to remove Chem-Film.
11. Break inside and outside corners of both cylinders, 1/16-inch maximum and 1/32-inch minimum, across face with a vixen file.
12. Draw file the entire joint face of the top cylinder.
13. Draw file the entire joint face of the bottom cylinder.
14. Remove residue by vacuum without touching parts.
15. Weld joint must be protected from contamination if welding is delayed, following fit-up.
    (a) Aluminum foil to be taped over weld joint without touching joint surfaces.
16. Scrapping method to be used in localized areas, as required, during cleaning operation of cylinders.
17. Prior to lowering of the top cylinder and prior to start of tack welding, white light inspection shall be performed by Quality Assurance. Black light inspection shall be performed by Manufacturing under the surveillance of Quality Assurance.

Each of the welding packages scheduled for use on the subject weld shall have an assigned Manufacturing weld engineer. Modification of any procedure or welding parameters (within specification requirements) shall be the responsibility of the weld engineer.

Preweld Closeout: The following items shall be checked prior to each weld procedure:
1. Welding parameters, pages 8 and 9
2. Ground clamp and signal leads
3. Shielding gas supply moisture content
4. Torch lead angle
5. Skate drive engagement
6. Torch-seam alignment
7. Wire guidelines
8. Trial run of welding skate on complete length of trace (smooth operation)
9. Tungsten configuration

Schedule No. 00550	Revision Letter B	Page 3 of 11

Welding Procedure: (Cont)

PROCEDURE NO. 1, MACHINE TACK (INTERMITTENT AND COVER TACK)

1. See weld parameters on pages 8 and 9
2. Manufacturing shall determine initial tack points from preliminary gap and offset measurement.
3. Initial tack points shall not contain gap conditions in excess of 0.040 inch.
4. Cylinder positioning tacks approximately 3 inches long on approximately 10-inch centers shall be utilized. Each machine shall tack diametrically opposite the other when possible.
5. Filler wire shall not be turned off as torch passes over the intermittent tack during the full tack procedure.

PROCEDURE NO. 2, PENETRATION PASS

NOTE: X-ray after completion will be the option of Manufacturing.

1. Penetration pass shall be accomplished using the weld parameters listed on pages 8 and 9.
2. In the event penetration is not achieved within 3 inches of the weld start or lost at any time during the welding, the weld engineer may adjust parameters of arc voltage and arc current as deemed necessary, within specification limitations.
3. In the event of a machine malfunction, the remaining open seam shall be welded, prior to any repair action.
4. In the event of extenuating circumstances, such as adverse environmental conditions, joint fitup, etc., the weld engineer shall have the prerogative to divide the length of the penetration pass into eighths or twelfths, or as deemed necessary.
5. Remote current override may be used during penetration weld pass (within schedule requirements).
6. Prior to the cover pass operation, the weld bead may be contoured to a smooth surface.

PROCEDURE NO. 3, COVER PASS NO. 1

1. Parameters for cover passes are delineated on pages 8 and 9 of this document.

PROCEDURE NO. 4, COVER PASS NO. 2

1. Parameters are delineated on pages 8 and 9.

PROCEDURE NO. 5, COVER PASS NO. 3 (OPTIONAL)

1. Parameters are delineated on pages 8 and 9.

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Welding Procedure: (Cont)

SPECIAL INSTRUCTIONS

1. Starting, stopping, and restarting due to malfunction, power failure, etc., shall be the responsibility of the weld engineer.
2. Variations in parameters per MA0107-016 specification must be controlled by the weld engineer.
3. Cleaning of weld beads, when necessary for inspection, shall be done using a hand-held stainless steel wire brush, brushed in one direction only.
4. Check each machine performance on a test plate (bead-on plate).
5. The penetration weld pass shall be accomplished within the range of 395 to 410 amps, and with the parameters on pages 8 and 9.
6. At point of tack, the gap shall not exceed 0.040 inch.
7. Quality Assurance will provide surveillance for all supplemental welding operations.
8. If the arc is not established with a normal sequence start, a touch start is strictly forbidden. Sequence out and make the necessary correction.
9. In the event an excessive offset condition exists that cannot be corrected by reheating and pressure, a tack may be broken provided that complete concurrence of Manufacturing, Manufacturing Engineering, and Quality Assurance is obtained. No filler wire shall be used in the reheating operation.
10. Gap control using stainless steel spacer shims shall be at the option of Manufacturing.

SUPPLEMENTAL WELD OPERATIONS

1.0 One supplemental weld operation shall be permitted to correct any condition listed below provided complete records of the action are presented to Quality Assurance for permanent future reference regarding all information, such as joint configuration prior to rework, resulting configuration, welding parameters, etc. Only one attempt to correct the condition shall be allowed without M.R. action. Any M.R. shall reflect all conditions and actions of the supplemental operation.

1.1 Method (1): Supplemental weld operation for the conditions of undercut, lack of fill, incomplete penetration, suck-back, or off-center weld nugget.

1.1.1 Condition: Undercut, lack of fill, or suck-back

Supplemental Rework Procedure: Use cover pass weld parameters.

1.1.2 Condition: Incomplete penetration or off-center weld nugget.

Supplemental Rework Procedure: Use penetration pass welding parameters.

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Welding Procedure: (Cont)

1.2 Method (2): Supplemental weld operation for the condition of oxides and/or porosity that unquestionably require repair.

1.2.0 Limitations: Supplemental welding operations to remove oxides and porosity shall be performed only if the defect size exceeds the following limits:

LO_2 GIRTH	POROSITY CLUSTER Area (Square Inches)	SINGLE PORE Diameter (Inches)	OXIDE Length (Inches)
INBOARD SIDE OF WELD	2 x Specification Allowables	0.174	0.25
OUTBOARD SIDE OF WELD	1.5 x Specification Allowables	0.150	0.25

Defects less than the limits given in the above table (and not buyable per specification) shall be withheld for Material Review evaluation.

1.2.1 For weld nugget groove-outs not exceeding 0.100 inches in depth, the following procedures shall be followed:

1.2.1.1 Grinding to a maximum depth of 0.100 inches (as measured from the parent metal surface) shall be permitted prior to the application of the cover pass.

1.2.1.2 Maximum groove-out width shall be 0.210 inches.

1.2.1.3 Grinding shall not increase the weld bead width.

1.2.1.4 The following parameters shall be utilized for filling the 0.100 deep groove-out:

1.2.1.4.1 Potential - 13.0 volts

1.2.1.4.2 Current - 255 amps

1.2.1.4.3 Weld Rate (IPM) - 15.0

1.2.1.4.4 Filler Wire Rate (IPM) - 50.0

1.2.1.4.5 Programmer settings shall be set as given in Column 3, pages 8 & 9.

1.2.1.5 When a supplementary pass has been applied prior to the cover pass, then none will be permitted after the cover pass in the same area.

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Welding Procedure: (Cont)

1.2.2 For weld nugget groove-outs between 0.100 inch to a maximum of 60% T in depth, the following procedures shall be followed:

1.2.2.1 Radiographically inspect to establish exact location of defects.

1.2.2.2 Grinding shall not increase the weld bead width.

1.2.2.3 Groove to a depth as required to remove the defects (not to exceed 60% of the material thickness) using a ZT-550 cutting tool or equivalent. (See sketch of groove configuration on next page.)

1.2.2.4 Pores that are open to the surface at the bottom of the groove-out may be opened and cleaned to allow welding without outgassing. Pores open to the base of the groove-out that extend to a depth exceeding 70% of the parent metal thickness shall be submitted to M. R.

1.2.2.5 A verification operation will be performed by grooving a plate to 60% of parent material thickness and welding one pass in the base of the groove. Radiographic inspection of this plate is not required unless requested by Quality Assurance.

1.2.2.6 Weld fill using the weld parameters presented on Page 10 and 11.

1.2.2.7 Radiographic inspect after each weld pass; if review of the X-ray film reveals a condition that does not meet the applicable specification requirements, one groove-out operation shall be permitted to remove the last weld pass only. Thereafter, upon discovery of a defective area, it will be submitted to Material Review for disposition.

1.2.2.8 The starting and stopping sequence will be such that each succeeding filler pass extends over the previous start and stop area.

NOTE: The use of the current override shall be permitted to <u>reduce</u> current (within specification requirements) <u>only</u>.

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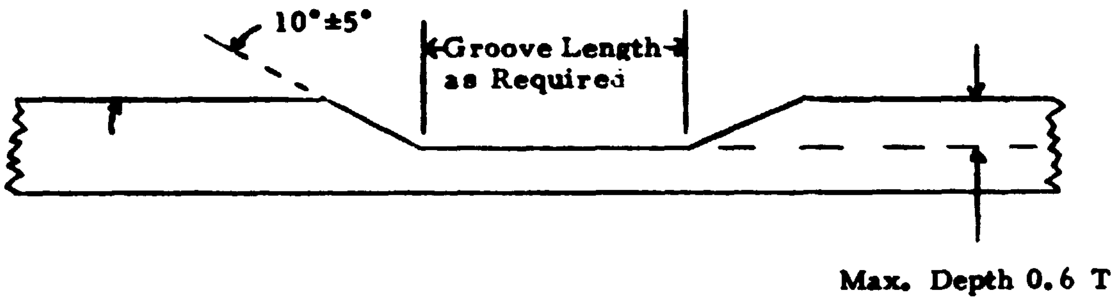
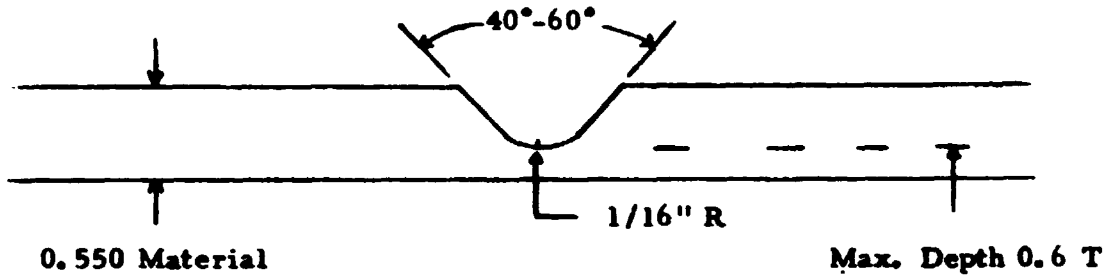
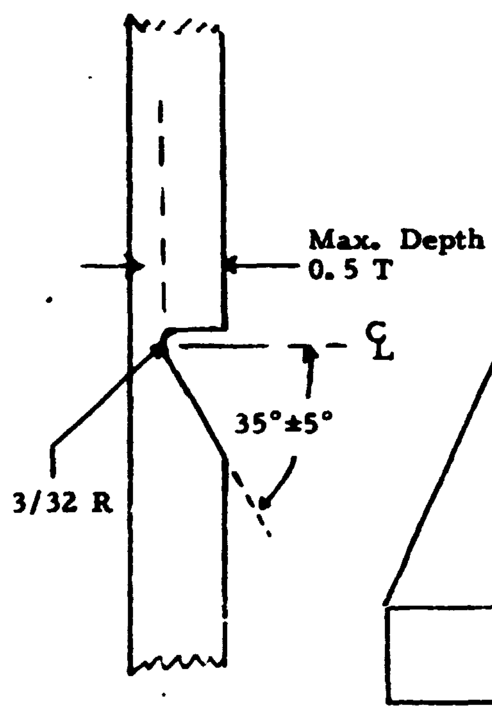
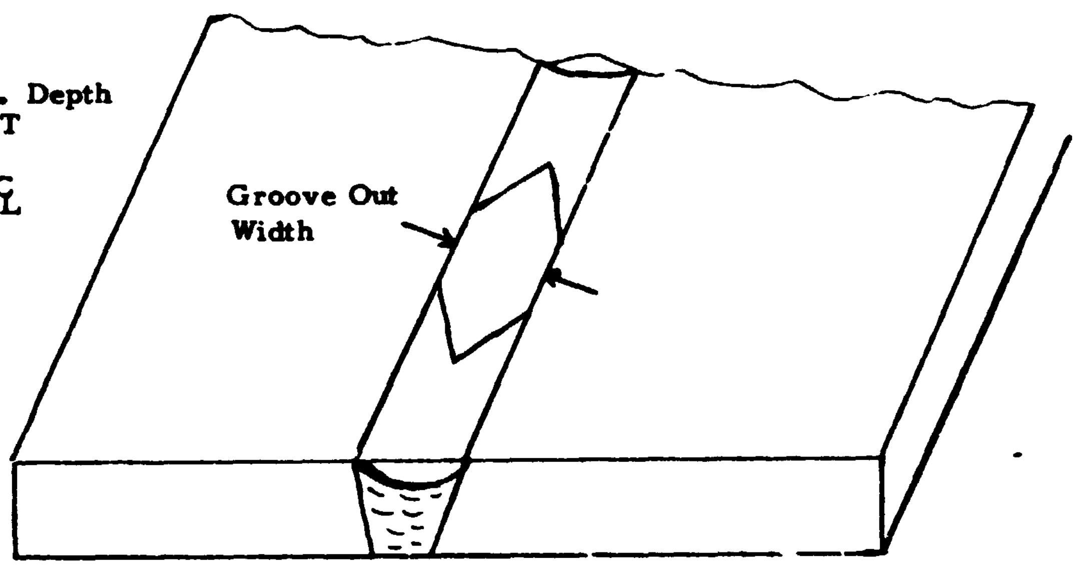
Welding Procedure: (Cont)









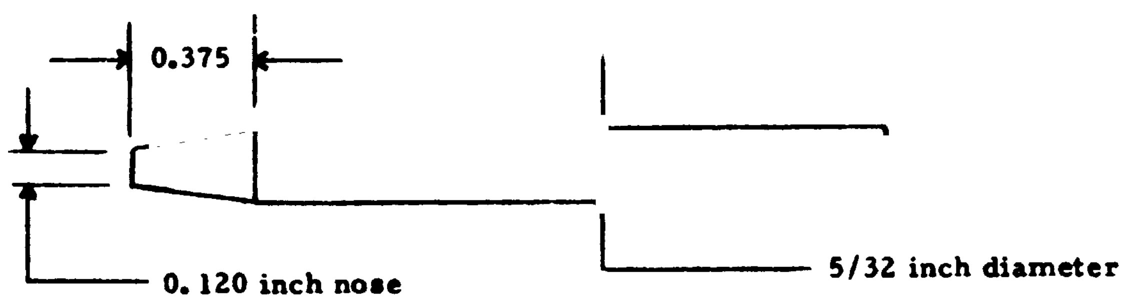
Welding Procedure: (Cont)

	INTERMITTENT COVER TACK	PENET. PASS	COVER PASS (1, 2, 3)
Travel	12.0	5.5	15.0
TIG Voltage	11.5	11.0	13.0
Amperes	290.0	400.0	255.0
Wire Feed	10.0	0	60.0
Current Stop Delay (Potent.)	6.0	5.0	6.0
Current Stop Delay (Switch)	0.15	15-30	0-15
Initial Current	200.0	250.0	200.0
Initial Slope Rate	0.50	-	-
Final Current	50.0	-	-
Final Slope Rate	6.0	-	2.0
Travel			
Initial Speed	7.5	-	-
Initial Slope	0.50	-	-
Final Speed	15.0	20.0	-
Final Slope	6.0	10.0	-
Arc Head			
Rate of Response	2.0 to 8.5	-	-
Initial Voltage	12.0	-	-
Initial Slope	0.30	-	-
Final Voltage	15.0	13.0	-
Final Slope	6.0	5.0	1.55
TIG Wire Feed			
Retract	8.0	-	-
Initial Voltage or Speed	20.0	-	-
Slope Rate	0.50	-	-
Final Voltage or Speed	0.30	-	-
Slope Rate	1.40	-	-
Gas			
Preflow (Switch)	0-15	-	-
Preflow (Potent.)	10.0	-	-
Post Flow (Switch)	0-15	15-30	0-15
Post Flow (Potent.)	10.0	-	-
Wire			
Start Delay Switch	0-15	-	-
Start Delay Potentiometer	1.50	1.0	-
Stop Delay Switch	0-15	-	-
Stop Delay Potentiometer	2.5	4.0	-

Welding Procedure: (Cont)

	INTERMITTENT COVER TACK	PENET. PASS	COVER PASS (1, 2, 3)
Travel			
Start Delay Switch	0-15	-	-
Start Delay Potentiometer	1.00	5.00	1.00
Stop Delay Switch	0-15	15-30	0-15
Stop Delay Potentiometer	6.50	6.5	0.5
Head Unlock Delay Switch	0	-	-
Head Unlock Delay Potent.	0	-	-
Tungsten Taper	3/8" with 0.120 nose	-	20°
Tungsten Dia.	5/32	-	-
Weld Angle	90°+7°	-	-
Gas Flow	110 CHF		

NOTE: The dashes (-) signify same settings in previous column.



Tungsten Electrode Configuration
for Penetration Pass

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Parameters for supplemental welding operations.

Welding Procedure: (Cont)

	1st	2nd	3rd	4th	5th
Travel	10	10	10	10	-
TIG Voltage	12	12	12	12	-
Amperes	230	240	240	240	-
Wire Feed	25	35	35	50	-
Current Stop Delay (Potent.)	5.00	-	-	-	-
Current Stop Delay (Switch)	0-15	-	-	-	-
Initial Current	200	-	-	-	-
Initial Slope Rate	0.50	-	-	-	-
Final Current	50.	-	-	-	-
Final Slope Rate	1.50	-	-	-	-
Travel					
Initial Speed	7.5	-	-	-	-
Initial Slope	0.50	-	-	-	-
Final Speed	17.0	-	-	-	-
Final Slope	1.55	-	-	-	-
Arc Head					
Rate of Response	2-8	-	-	-	-
Initial Voltage	12.0	-	-	-	-
Initial Slope	0.30	-	-	-	-
Final Voltage	15.0	-	-	-	-
Final Slope	1.5	-	-	-	-
TIG Wire Feed					
Retract	2-10	-	-	-	-
Initial Voltage or Speed	20.0	-	-	-	-
Slope Rate	0.50	-	-	-	-
Final Voltage or Speed	30.0	-	-	-	-
Slope Rate	1.40	-	-	-	-
Gas					
Preflow (Switch)	0-15	-	-	-	-
Preflow (Potent.)	8.00	-	-	-	-
Post Flow (Switch)	0-15	-	-	-	-
Post Flow (Potent.)	10.0	-	-	-	-

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00550	E	Page 11 of 11

Parameters for supplemental Welding Operations

Welding Procedure: (Cont)

	1st	2nd	3rd	4th	5th
Wire					
Start Delay Switch	0-15	-	-	-	-
Start Delay Potentiometer	1.5	-	-	-	-
Stop Delay Switch	0-15	-	-	-	-
Start Delay Potentiometer	2.5	-	-	-	-
Stop Delay Switch	0-15	-	-	-	-
Stop Delay Potentiometer	0.5	-	-	-	-
Travel					
Start Delay Switch	0-15	-	-	-	-
Start Delay Potentiometer	2.5	-	-	-	-
Stop Delay Switch	0-15	-	-	-	-
Stop Delay Potentiometer	0.5	-	-	-	-
Head Unlock Delay Switch	0				
Head Unlock Delay Potent.	0				
Tungsten Taper	45°				
Tungsten Dia.	1/8"				
Weld Angle	90°				
Gas Flow	110 C.F.H.				

AMENDMENT 1

REF: Item 2 of Preweld Closeout, Page 2 of 11

1. Connect the sensing lead directly to the stage.
2. Connect the (backup) earth to ground lead to the stage (girth weld).
3. Thoroughly check remachined electrodes (those which have been salvaged from previous welds) prior to welding the penetration pass.

DEPT.	APPROVALS	DATE
Mfg.		
QA		
Eng.		

FORM 971-D-2 New 4-63 NAA-S&ID